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29.
36.

ERUPTION OF MOUNT VESUVIUS IN 1794.

OUTLINES

5. 11. 1829.

OF

23

GEOLOGY.

BY

WILLIAM THOMAS BRANDE, F.R.S.,

PROF. CHEM. R. I., ETC.

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THE PRESIDENT AND MEMBERS

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THEIR FAITHFUL SERVANT,

THE AUTHOR.

ADVERTISEMENT.

The following pages present an Outline of the different Courses of Lectures which I have delivered in the Royal Institution upon the subject of Geology: they are intended to convey to the uninitiated an idea of the object and uses of that department of science, and to draw his attention to the various collateral branches of natural knowledge connected with, or emanating from, geological studies. I have, therefore, avoided all unnecessary introduction of technical terms; and, in adverting to controversial and theoretic points, have almost exclusively limited myself to brief notices, or mere references to authorities.

May, 1829.

CONTENTS.

SECTION I.

Page

Preliminary Remarks—Objects of Geology—Early Theorists—Burnet, Woodward, Leibnitz, Whiston, Mitchell, Whitehurst, Buffon, Pallas, Kirwan, De Luc, Lehman.—Neptunists and Plutonists—Wernerians and Huttonians—Uses of Geology—Arrangement 1

SECTION II.

Modern Geology—Substances of which Rocks are composed—Silica—Lime—Alumina—Magnesia—Succession of Strata—Superior, supermedial, medial, submedial, and inferior Rocks—Superficial Appearances of the Earth—Valleys . . . 32

SECTION III.

Organic Remains peculiar to the Superior Strata—Alternation of Fresh Water and Marine Shells—Parallel Roads of Lochaber—Beds of Gravel—Evidences of the Deluge—Caverns containing the Remains of Quadrupeds 54

SECTION IV.

Supermedial Rocks—Chalk—Its aspects and varieties—Green-sand—Iron-sand—Oolite—Portland-stone—Lias—Fossils peculiar to these Strata 79

SECTION V.

Red Sandstone—Gypsum—Salt—Coal—Dikes and other peculiarities of the Coal Strata—Origin of Coal 91

SECTION VI.

Page
Mountain Limestone—Lead Measures—Cross Veins—Toadstone—Aspect of Limestone districts—Old red Sandstone—Grauwacke—Slate—Curvatures and Contortions of Strata . . 104

SECTION VII.

Granite ; its varieties and aspects—Gneiss—Mica-slate—Syenite—Porphyry—Marble—Serpentine—Quartz Rock—Granite Tors—Decomposing Granite—Association of Rocks in Glentilt—Theories—Rocks at the Fall of Fyers 126

SECTION VIII.

Trap Rocks—Basalt—Greenstone—Toadstone—Amygdaloid—Pitchstone—Instances of these Rocks—Staffa—Giants' Causeway—Isle of Sky—Theories of these Rocks 154

SECTION IX.

Metallic Veins—Theories of their Origin—Their Peculiarities—Cross Courses, and other Irregularities—Modes of Working and Discovering Veins 170

SECTION X.

Of the Decomposition and Decay of Rocks—Agencies of Water, and of Changes of Temperature—Relative Durability of Rocks—Sources of Reproduction 191

SECTION XI.

Phenomena of Hot Springs, Earthquakes, and Volcanoes—Submarine Explosions—Extinct Volcanoes—Vesuvius—Etna—Theories—Conclusion 215

LIST OF THE WOOD-CUTS.

The Frontispiece is a view of the Eruption of Mount Vesuvius in the year 1794, taken from an original drawing, done from Nature at Pausilipo (from Sir William Hamilton's Campi Phlegræi).

The wood-cut at page 1, is from a sketch by Sir H. Davy, illustrative of the general aspect of the different classes of rocks. The rugged and abrupt summits of the primitive mountains are seen in the background, skirted by the transition series on the left, and the secondary rocks on the right.

The head of the Second Section, page 32, is a view of the Parallel Roads of Lochaber, from one of the plates annexed to a description of them, by Thomas Lauder Dick, Esq., published in the Ninth Volume of the Transactions of the Royal Society of Edinburgh.

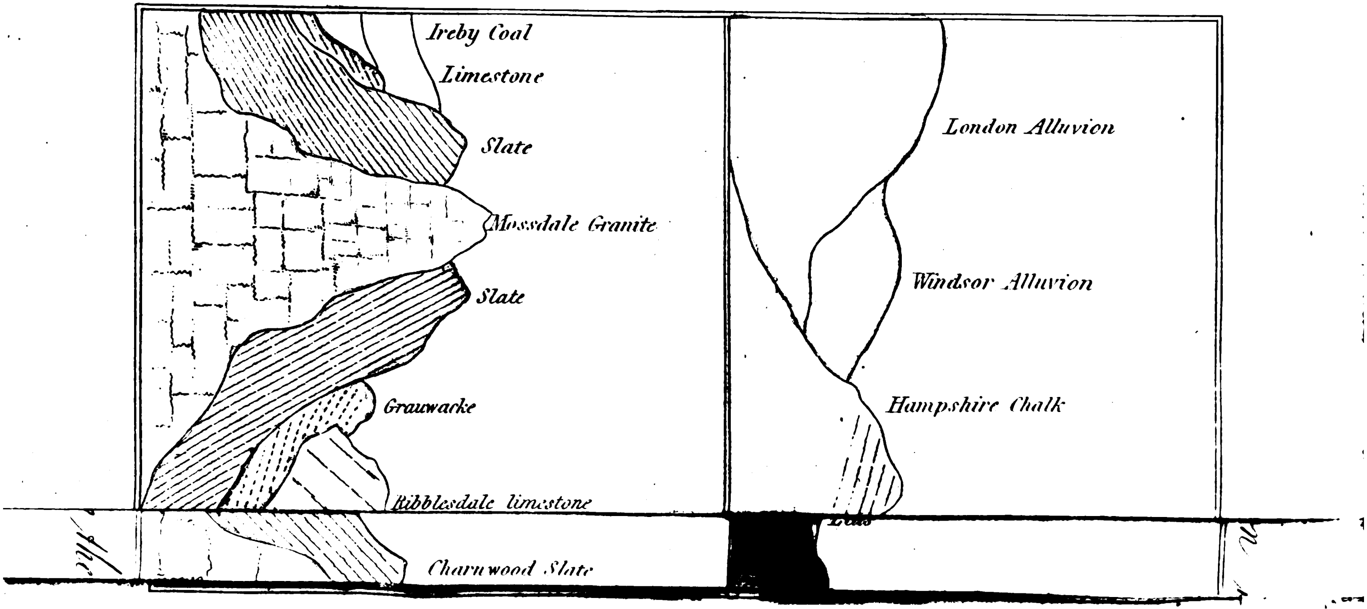
Page 54.—The wood engraving is a copy of the vertical section of the Cavern at Galenreuth in Franconia, published by Dr. Buckland in the Reliquiæ Diluvianæ. The entrance is from six to ten feet high, and is separated by a pillar of stalactite from the larger chambers; the floors are stalagmite, and the great deposit of bones beneath them are mixed with fragments and gravel.

Page 66.—The Skeleton of the Siberian Elephant, from Mr. Stokes's drawing.

Page 79.—The wood-cut is from one of Mr. Webster's drawings engraved in the Second Volume of the Geological Transactions. It is ing granite rocks are for the most part in a state of rapid decomposition.

Section XI., page 215.—The wood-cut is copied from Capt. Tillard's sketch of the appearances that attended the formation of a volcanic island, thrown up in the ocean off the Island of St. Michael. The principal phenomena are adverted to in the text.

OUTLINES OF GEOLOGY.


Ireby Coal
Limestone
Slate
Mossdale Granite
Slate
Grauwacke
Ribblesdale limestone
Charnwood Slate
London Alluvion
Windsor Alluvion
Hampshire Chalk
Lias

OUTLINES OF GEOLOGY.

GENERAL ASPECTS OF ROCKS.

SECTION I.

Preliminary Remarks—Objects of Geology—Early Theorists—Burnet, Woodward, Leibnitz, Whiston, Mitchell, Whitehurst, Buffon, Pallas, Kirwan, De Luc, Lehman.—Neptunists and Plutonists—Wernerians and Huttonians—Uses of Geology—Arrangement.

I SHALL endeavour, in these preliminary remarks, to give a very brief outline of the origin and progress of geological science; to explain particularly the mode of pursuing it which it is proposed, upon the present occasion, to recommend; to show the interest and the usefulness of the study in its various applications, as illustrating the natural history of our planet; as unfolding those adjustments of inanimate nature which are calculated to display the wisdom of the creation; as leading us to results useful in the arts of life; and as propounding to the inquisitive mind an infinite variety of questions and speculations connected with the causes of the effects which we now perceive; with the events which they announce as having happened at remote and obscure periods of the history of the Earth; and with the various revolutions and changes which our globe seems destined to undergo, by the continued operation of the powers now active, and by that perpetual warfare of the elements to which its surface is continually submitted. The bare mention of these, the genuine and legitimate objects of Geological science, naturally brings to the mind the awful and magnificent account of the creation, conveyed to us in scriptural history; and geological writers have not unfrequently attempted to combine their speculations with the announcements of holy writ. Mixing up the chronology of Moses and the history of the deluge with their own short-sighted speculations, and with observations hastily made and imperfectly reasoned upon, they have presumed, on the one hand, to verify and illustrate, and on the other, to question and controvert. But the arrogance of imperfect knowledge is nearly equally prevalent in both; "nothing," says Lord Bacon, "is more pernicious than to canonize error:" and again, adverting to the blending of natural philosophy with sacred writ, he calls it

" seeking the dead among the living," and justly observes, that " such vanity is so much the rather to be restrained and suppressed, as from the wild mixture of divine things with human, arise, not only fantastical philosophies, but heretical religions."

I shall not, therefore, now, or upon any other occasions, meddle with the adjustments of these and like speculations to the records of Holy Writ. If, in the laborious path of experimental investigation, we are occasionally rewarded with the discovery of some new adaptations of causes and effects, which had before escaped notice, but which demonstrate how all things on earth are made to work together for good,—the discovery strengthens our faith, and calls forth the best feelings of which the human heart is susceptible; but we must not presume to submit the aptitude of Nature's arrangements to the feeble powers of human decision, to doubt her perfection because our imbecile capacities cannot attain its comprehension, or to found our proofs of the existence or even of the attributes of the Deity, upon the limited, imperfect, or ideal conception of the excellence of Nature's works, of which the human understanding is capable.

Far, therefore, from endeavouring to explain or controvert the arguments which have thus been by some annexed to, and blended with geology, I shall altogether omit them, referring such as are interested in the legitimate part of the discussion, to the masterly work of Mr. Granville Penn, entitled " A Comparative Estimate of the Mineral and Mosaical Geologies," and I shall almost exclusively confine myself to the detail of those facts which lead to useful conclusions: hypotheses I shall not enlarge upon, because they rather amuse than instruct; and I shall only lightly touch upon such theories as are remarkable for their notoriety, or important from their connexion with, and illumination by, the leading facts of our science: but upon this subject I propose to explain myself more fully in another place.

Geological writers may be divided, into those who are purely speculative; those who have built theories upon the examination of the structure of the earth's surface, or, at least, profess to do so; and those who, discarding speculation, and theory, have contented themselves with the abstract detail of facts.

Of the former class, Dr. Thomas Burnet *, who must not, as he sometimes has been, be confounded with the celebrated Bishop of Salisbury, with whom he was contemporary, stands pre-eminent. This writer, in his Sacred Theory of the Earth, which was originally published in Latin, between 1680 and 1690, and translated into English at the express request of Charles II., and which has been extolled for its eloquence and ingenuity by many of the most eminent

---

* The Sacred Theory of the Earth, containing an Account of the Original of the Earth, and of all the general changes which it hath already undergone, or is to undergo, till the consummation of all things. (8vo.) London, 1726.

authors, has taken a review of the past changes of the globe, contrasts them with those it is now undergoing, and foretells those which it is to suffer; and as the name of Burnet is continually occurring in geological history, it will not, I trust, be thought irrelevant, briefly to enumerate his opinions, more especially as this is the only time that I shall mention him or his doctrines.

In the first place, he ransacks scriptural and profane history, selecting from each such statements as suit his particular object, and endeavours to show that the primeval earth, as it arose out of elementary chaos, was of a form and structure different from that which it now exhibits, and so contrived as to contain within itself the materials necessary to the production of an universal deluge. He tells us, that when the elements separated from the original fluid mass, the heaviest particles tending to a centre, constituted a nucleus upon which water and air afterwards assumed their respective stations. The air, however, was not as we now see it, a transparent attenuated medium, but it was loaded with exhalations and impurities, which it gradually let fall upon the surface of the water, and then floated upon the whole in cloudless serenity. The deposited matter, constituting a rich crust, sent forth its vegetable productions, and soon became clothed with uninterrupted verdure; every thing was smooth, soft, and regular, and there was, he says, an universal spring, for the plane of the ecliptic was coincident with that of the equator. In process of time, however, the green and even surface just described began to suffer from the continuous action of the sun's rays, which formed cracks and fissures that ultimately extended to the abyss of waters beneath, and these being sent forth by elastic vapours expanded by heat, soon inundated the superficies; an universal deluge ensued; and, in the violent shocks and concussions that attended it, rocks and mountains and all the inequalities of the present surface had their origin: then the waters gradually subsided into the residuary cavities forming the ocean, and partly were absorbed into the crevices of the disjointed strata and nucleus; vegetation began to re-appear, and the once uninterrupted and uniform surface was now broken up into islands and continents, and mountains and valleys.

Absurd, as from this condensed and unadorned sketch, Burnet's narrative must appear, it is told with such ingenuity and elegance, and supported with so much erudition, as to entitle it to all the merit that can belong to a highly elaborate and poetical fiction. Addison has eulogised it in Latin verse *, Steele has praised it in the "Spectator," and Warton, in his "Essay on Pope," ranks the author "with the select

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* Addison's Ode to Burnet is attached to the English edition of the Sacred Theory above referred to. It is in the ordinary fulsome style of that period. The following stanza is a specimen—

Jamque alta cœli mænia corruunt
Et vestra tandem pagina, proh nefas!
BURNETTE, vestra augebit ignes,
Heu! socio peritura mundo.

few in whom are united the great faculties of the understanding,—judgment, imagination, memory."

But, although Burnet received and deserved the encomiums of the learned, the praise that he earned is rather that of the poet than of the philosopher. Dr. Flamstead, adverting to his rich vein of poetical diction, told him "that there went more to the making of a world than a well-turned period;" and Mr. Warren, Dr. Herbert Crofte, Dr. Beaumont, and Dr. Keill * of Oxford, each refuted and abused him as a theorist. Yet Burnet's work continued to be read, not for its philosophic truths or theoretic consistency, but for its splendid imagery, noble sentiments, and sublime conceptions. The following passage has been highly admired; it is a funeral oration over the globe: "Let us now," says he, "reflect on the transient glory of the earth; how, by the force of one element breaking loose on the rest, all the beauties of nature, each work of art, and every labour of man, are reduced to nothing; all that once seemed admirable, is now obliterated; all that was great and magnificent has vanished; and another form and face of things, plain,

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* An Examination of Dr. Burnet's Theory, &c., by J. Keill, A.M. of Baliol Coll. Oxon. Second Edition, 1734, 8vo. "He (Burnet) begins his discourse with the saying of an old heathen, that philosophy is the greatest gift that ever God bestowed on man; but it is plain to any who will be at the pains to read his book, that God has thought fit to bestow but very little of that great gift upon him, and that the world may not say this is ill nature, I will give them a taste of his philosophy," &c.

This is the general style of the "Examination."

especially Minerals; as also of the Sea, Rivers, and Springs. With an account of the Universal Deluge, and of the Effects it had upon the Earth." This essay, which is scarcely so much known as it deserves, excited a good deal of bustle amongst the philosophers of the period in which it was written; it was attacked, canvassed, examined, and defended, and called forth all those ephemeral answers, replies, and rejoinders, which flutter about controversy. Woodward did not confine himself to geology, he attracted some notice as a physician, and more as an antiquary: in his last will he founded a lectureship in the University of Cambridge; he died in 1728.

When we consider the untoward circumstances of Dr. Woodward's education, and the obstacles that in early life were opposed to the natural bent of his genius or inclination, we must allow him no small merit in encountering and overcoming them. At the same time, his life and writings are a good deal sullied by peevish jealousy and visionary enthusiasm. He is ridiculed by Pope, under the name of Vadius, in his *Moral Essays*; and again in several parts of the *Memoirs of Scriblerus*, where an ancient shield, which the Doctor possessed, becomes the chief subject of the poet's merriment.

Among the correspondents and opponents of Woodward, we meet with several authors whose works are never read, and whose names are falling fast into entire oblivion; there were others of more celebrated memory, and among them Leibnitz, who, towards the end of the 17th century, published his *Protogæa*, in which there is little more than crude and improbable speculations relating to the agency of fire upon a supposed chaotic mass. He conceives the earth to have been in a state of combustion for many ages, and at length to have gone out for want of fuel. A glassy crust was thus formed, which gave rise to sand and gravel; other kinds of earth resulted from sand and salt; and as the globe cooled, the water which had before been kept in the state of steam assumed fluidity, and falling to the earth, produced the ocean. Nor are the geological opinions of Whiston, well known as having elicited the libellous witticism of Swift, deserving of more attention, though his work, published in 1696, entitled "A New Theory of the Earth, wherein the Creation of the World in Six Days, the Universal Deluge, and the General Conflagration, as laid down in the Holy Scriptures, are shown to be perfectly agreeable to Reason and to Philosophy," gained him great notoriety.

It would, however, be an injustice to Whiston, were I to pass him by without quoting Locke's eulogium of his "Theory of the Earth;" who says, in a letter to Mr. Molyneux, bearing date Feb. 22, 1696:—"I have not heard any one of my acquaintance speak of it but with great commendations, and, as I think, it deserves: and, truly it is more to be admired that he has laid down an hypothesis, whereby he has explained so many wonderful and before inexplicable things, in the great changes of this globe, than that some of them should not easily go down with some men, when the whole was entirely new to all. He is one of those sort of writers, that I always fancy should be most esteemed and encouraged. I am always for the builders who bring some addition to our knowledge, or, at least, some new things to our thoughts." But Locke's opinion upon such a subject is not entitled to any especial weight. I have perused Whiston's book, without being able to find any particular merit in his speculations, and am rather inclined to side with his opponents, in forming an estimate of its value.

About this time a central fire was resorted to for the purpose of solving certain geological problems, by so many writers, that it is difficult to say to whom the merit, if such it be, of the invention belongs. Becher's *Physica Subterranea* deserves especially to be consulted in reference to this subject.

Towards the middle of the last century, geology began to assume a more regular scientific aspect; and among the earliest inquirers of this period, Mitchell and Whitehurst deserve something more than bare mention. The merits of the former writer have been overlooked, principally, I presume, on account of the title of his paper, which is in the *Philosophical Transactions* for 1760, "On the Cause and Phenomena of Earthquakes," a title under which we should not perhaps look for geological, and still less, for minute practical information. We are chiefly indebted to Dr. Fitton for bringing him into notice, in an able article on English Geology, contained in the *Edinburgh Review* for 1811. This very ingenious writer describes the general appearances of the strata, points out their analogies and differences, adverts to their inclination and disturbance in mountainous districts, and to their horizontality in flat countries; and, having explained, with much minute and practical perspicuity, the arrangement of the strata in England, he exemplifies its universal application to the general structure of the globe; and ingeniously represents it in the following manner. "Let a number of leaves of paper," he says, "of several different colours, be pasted one on another; then, bending them up together into a ridge in the middle, conceive them to be reduced again to a level surface, by a plane so passing through them as to cut off all the part that had been raised; let the middle now be again raised a little, and this would be a good general representation of most, if not all, large tracts of mountainous countries, together with the parts adjacent, throughout the whole world. From this formation of the earth it will follow, that we ought to meet with the same kinds of earths, stones, and minerals, appearing at the surface in long narrow slips, and lying parallel to the greatest rise of any large ridge of mountains; and so, in fact, we find them."

Mr. Mitchell's paper abounds in important geological generalizations, and he applies his theories and inquiries with much dexterity and success to the structure of the whole surface of the globe, as well as to its individual parts.

Whitehurst is another writer of considerable merit in the history of English geology: in early life he passed a great part of his time in Derbyshire, a county well suited to excite and satisfy a mind endowed with the desire of penetrating into the formation of rocks, and into the origin and history of organic remains. The fruit of these investigations he submitted to the world in 1778, in his "Inquiry into the Original State and Formation of the Earth *;" a work which, in its general outline and particular execution, does no small credit to the genius and diligence of the author. It is true, that much of it is tinctured by that unpropitious taste for cosmogony, which we have reprobated in preceding writers; but if we look to the practical details, we find them faithful to nature, and described with correct minuteness. To this point I need only quote the following passages. "The arrangement of the strata," he says, "is such, that they invariably follow each other as it were in alphabetical order, or as a series of numbers. I do not mean to insinuate that the strata are alike in all the different regions of the

---

* The works of John Whitehurst, F.R.S. London, 1792. "It is my intention (says Whitehurst in his preface) to trace appearances in nature from causes truly existent; and to inquire after those laws by which the Creator chose to form the world, not those by which he might have formed it, had he so pleased."

earth, with respect to thickness or quality, for experience shews the contrary; but that in each particular part, how much soever they may differ, yet they follow each other in a regular succession *."

In the writings of Mitchell, and of Whitehurst, then, we begin to discern something like a genuine and scientific investigation respecting the structure, position, and contents, of the strata that envelope our globe. But no one has proceeded to the forming of a theory of the earth, with the pomp and circumstance of Buffon †. It merits attention, not on account of its accordance with present appearances, or as affording plausible solutions of observed phenomena, but from the eloquence with which it is adorned, the extent of information it displays, and the popularity it derived from these sources.

He supposes the planets in general to have been struck off from the sun by a comet; that they consisted of fluid matter, and thence assumed a spherical form; and that by the union of centrifugal and centripetal forces, they are restrained in their present orbits. The earth gradually cooled, and the circumambient vapours condensed upon its surface, while sulphu-

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* In his description of Derbyshire, he mentions the resemblance of the Toadstone to Lava; and infers, from its appearance, situation, and effects, that it must have issued from below in an ignited state, that it must have been projected with great violence amidst the superincumbent strata, and that their displacements and irregularities are the consequence.

† Histoire et Théorie de la Terre et des Epoques de la Nature. 4 Vols. 8vo. Paris, 1800.

reous, saline, and other matters penetrated its cracks and fissures, and formed veins of metallic and mineral products. The scorified or pumice-like surface of the earth, acted upon by water, produced clay, mud, and loose soils, and the atmosphere was constituted of subtile effluviæ floating above all the more ponderous materials. Then the sun and winds, and tides, and the earth's motion, and other causes, became effective in producing new changes. The waters were much elevated in the equatorial regions, and mud, gravel, and fragments were transported thither from the poles: hence, says Buffon, the highest mountains lie between the tropics, the lowest towards the poles; and hence the infinity of islands which stud the tropical seas. The globe's surface, once even and regular, became now rough and irregular; excavations were formed in one part, and land was elevated in another; and during a period of ages, the fragments of the original materials, the shells of various fish, and different other exuviæ, were ground up by the ocean, and produced calcareous strata, and other lowland depositions. These relics of marine animals we find at such heights above the present level of the sea, as to render it more than probable that the ocean once entirely overwhelmed the earth.

Of such phenomena Buffon takes particular and extended notice, and draws from them a series of curious and minute conclusions; not however satisfactory or logical, inasmuch as many of the data they are founded upon are imaginary, not real. Every one who now contemplates the earth's surface, must trace upon it marks of the most dire and unsparing revolutions, which, from the present order of things, it appears impossible should re-occur, except by the united and continuous agency of the most active powers of destruction. This, says Buffon, arose from the soft state of the former crust of the earth; and those causes, now imbecile and slow in their operation, were then more effectually exerted, and results were obtained in a few years, for which centuries would not be insufficient.

This amusing theorist next proceeds to contemplate the production of rivers, which he regards as having cut their own way to the ocean, as gradually wearing down the mountainous lands, filling up vallies, and choaking their exits into the ocean by the transportation of finely divided materials. Thus every thing is slowly returning to its former state; the mountains will be levelled, the vallies heightened, excavations filled up, and the ocean will again cover the earth. I shall not enter into the various confutations of these speculative notions, nor dwell upon many modern theories to which they have given rise. Pallas, Kirwan, De Luc, and others, have animadverted upon, but can scarcely be said to have improved, Buffon's hypothesis; and as we set out with granting it to be the mere fabric of imagination, it would be folly to submit it to the solemnity of philosophic criticism.

Many other theories of the earth I pass over in silence, as containing nothing not to be met with in some of the already mentioned Cosmogonists. The authors have sometimes clothed their fictions in new dresses, or presented them under new forms; but if we remove the mask, Burnet or Buffon are instantly recognized. Thus, in pretending to advance learning, they have rather obstructed it, and have accumulated hypotheses without enriching science. They deserve that censure thrown upon certain writers by Dr. Johnson, who calls them the persecutors of students, and the thieves of time. Such, at least, I have found them.

Rouelle, perhaps, reasoned more correctly, and discriminated with greater judgment; but in the works of this period, one very important fact must not be overlooked, relating to the distinction insisted upon chiefly by Lehman, and some other continental authors, which may be made between rocks containing organized fossils, and those which are destitute of such remains; the former bearing evident traces of great revolutions and changes, the latter, apparently of an anterior date, and exhibiting no marks of animal or vegetable relics: the former, in the words of Lehman *, owing their formation to partial or local accidents and derangements; the latter coeval with the world. To these, which have since been called *secondary* and *primary* rocks, he added a third class, in which, as to position and structure, he professed to recognise the operation of the deluge; he presumed that they must have resulted from some great catastrophe, tearing up and modifying an ancient order of things. But in respect to the classification of rocks, it will be our business to speak more at length hereafter; and apprehensive of fatiguing the attention with matters rather curious than useful, and with details historical rather than practical, I shall only further trespass upon it by briefly adverting to the speculations of two comparatively modern theorists, whose opinions have, till very lately, divided the geologists of our own time, and who may be called the founders of its once op-

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* Traités de Physique, d'Histoire naturelle, de Mineralogie, et de Metallurgie. Par J. G. Lehman, et traduits de l'Allemand.—Paris, 1759. "Les montagnes sont des élévations de la terre de différentes hauteurs, dont quelques-unes sont composées de parties dures, solides, et pierreuses; d'autres sont composées seulement de parties terreuses; quelques-unes ont été créés en même tems que la terre, d'au-

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tres ont été formées par des accidens, ou par des évenemens qui ont eu lieu, en différens tems."—Vol. III. Sect. 3. "Il n'y a rien de plus naturel que de partager toutes les montagnes en trois classes. La premiere classe sera celle de montagnes qui ont été formées avec le monde. La seconde sera celle des montagnes qui ont été formées par une révolution générale qui s'est fait sentir à tout le globe. La troisième classe, enfin, sera celle de montagnes qui doivent leur formation à des accidens particuliers, ou à des révolutions locales." "Les montagnes de la première classe sont élevées, dont quelques-unes se trouvent isolées dans des plaines; mais qui, le plus ordinairement, suivent une longue chaine et traversent des parties considérables de la terre. Elles diffèrent des montagnes de la seconde classe: 1. Par leur élévation et par leur grandeur, qui surpassent celles de toutes les autres. 2. Par leur structure intérieure. 3. Par les substances minérales qui s'y trouvent." Ibid.

These passages are sufficient to shew the merits of Lehman as an original and acute observer, and have furnished subsequent geologists with the foundations of their arrangements.

posed schools; premising, however, that in their arguments and hypotheses, as in those of their predecessors, we shall find much that is blameful and faulty, mixed up with a body of practical and matter-of-fact information, of infinite use and value: indeed, though it is unfortunately my business to adduce many of these theories rather to refute, than to elucidate them; and though they are, with few exceptions, so many imaginary fabrics, displaying rather the follies than the genius of the wise, it must be remembered that to them we chiefly owe the practical foundations of geology.

It would be easy to shew that the theories, or rather hypotheses, of which we have now taken notice, contain the germs of those speculations and inquiries which in our own days have excited so much attention and controversy, under the name of PLUTONIAN and NEPTUNIAN doctrines—the Neptunists affecting to trace all the present appearances of the globe to the sole agency of aqueous solution, disintegration, and deposition; and the Plutonists denying the exclusive operation of water, but combining its powers with those of fire, and calling in the aid of both elements.

The credit, such as it is, of the NEPTUNIAN THEORY, is commonly given to Werner; and if we find in it all the faults of its predecessors, and all the erroneous reasoning of darker ages, it will, at the same time, be recollected, that to him belongs the principal merit of pointing out the order of succession which the various natural families of rocks are generally found to present, and of having himself developed that order to a considerable extent, with a degree of accuracy which before his time was unattainable, for want of proper methods of discriminating minerals and their compounds. There is one disadvantage and difficulty attending an attempt to expound Werner's doctrines,—which is, that we are obliged to take them at second hand, since he has not published any connected view of them himself; and moreover, the Professor and his scholars have generally affected a mysterious phraseology which it is very difficult to construe into common sense, or intelligible terms; and which is sometimes so harsh and uncouth as to border upon the ridiculous, when, at least, we attempt to put it into an English dress. The darkness which he has thrown round his doctrines seems, indeed, often as if it were expressly intended to keep them from the eyes of the vulgar and uninitiated, and may be compared to that mystic and symbolical language, in which the alchemists delighted to veil the accounts of their researches, and which after all were no great things, when by dint of much labour and study they were deciphered and done into plain and legible terms. In speaking, therefore, of Werner's theory, we can only avail ourselves of such transient glimpses as he has himself thought fit to give us, and must fill up the various chasms and breaks, with materials derived from the more extended and finished sketches and illustrations with which we have been favoured by his pupils and disciples. Werner's theory then amounts to this:—The matter of our globe was once in a fluid state, or at least its nucleus was enveloped by a chaotic solution, of such a nature as to retain the various earthy bodies found in the lowest strata in chemical combination; but this state of things was of short duration, and the chaos began to deposit a variety of crystalline aggregates, such as the different species of granite, certain kinds of slates, or, as they are more technically called, schists; the genuine kinds of marble, serpentine, and porphyry, and a few other more equivocal compounds. These constitute the *primitive* rocks or formations of the Wernerian school; they are supposed to have had their origin antecedently to the creation of living beings; they are more or less crystalline in their texture, and never contain any organic remains or rounded pebbles.

The second class of rocks included in this arrangement, are supposed to have been formed during the *transition* of the Earth from its chaotic to its habitable state. They are partly crystalline aggregates, and partly mechanical deposits; they contain fragments of pre-existing rocks, and are sparingly interspersed with imperfect remains of some of the lower orders of animals: certain dark-grey compact limestones, and rocks composed of fragments imbedded in a slaty paste, are the leading members of this family.

It is, then, imagined, that the elements, acting upon these older rocks, tended to their attrition and disintegration, and that several substances being mechanically diffused throughout the waters that covered the primitive and transition series, were deposited upon them, in successive layers, in a horizontal position. These are Werner's *Flœtz* rocks: they not only contain, but even abound in, vegetable and animal remains; and among the latter, skeletons of amphibious animals are not uncommon. Certain limestones, red sandstone, coal strata, lias, and chalk, and some of the sandstones, belong to this division.

Lastly, we find depositions of sand, gravel, and clay, of the bones of quadrupeds, accumulations of peat, and some other substances now in progress of accumulation or deposition, which are included under the term *alluvial* formations.

The fifth class contains the produce of volcanic fires, and of more partial combustions. So that under one or other of these classes, or *formations*, as they are theoretically called, it is supposed that the various substances occurring amongst our rocks and strata may be included. It would be premature to descant upon or criticise this theory, without more particular notice of the facts upon which it rests, and of those which militate against it; but when in the possession of details, we shall be borne out in asserting, that it is, in all points, weak and unsatisfactory; that the very idea of an universal solvent, and of crystalline, succemented by mechanical deposits, is at variance with all experience or analogy; in short, that it includes an unwarrantable accumulation of hypotheses, assigning opposite qualities to the same agent; and that, like most of its predecessors, it is equally at variance with nature, and with itself—in a word, that it is a system which might pass for the invention of an age when sound philosophy had not as yet alighted on earth, nor taught man that he is but the minister and interpreter of nature, and can neither extend his power nor his knowledge a hair's breadth beyond his experience and observation of the present order of things."

The PLUTONIC THEORY, as it is generally though not quite properly termed, owes its origin to Dr Hutton, and proceeds upon principles differing from those of the ancient Vulcanists, at the head of whom we may place Whitehurst, and entirely at variance with the leading tenets of the School of Freyburgh. It has been defended by the late Mr. Playfair, under the term of the *Huttonian Theory*, and his "Illustrations" have by some been ranked among the most eloquent of scientific compositions; but he sometimes indulges too much in doctrines which neither experiment nor analogy are competent to sanction, and which are rather adapted to delight the fancy than to convince the reason.

The Huttonian theory supposes the materials which compose the present surface of the globe to have been derived from the action of water upon a former order of things; that they are, in fact, the debris or ruin of ancient continents, which have been pulverized and worn away by the continuous operation of torrents and currents of water, which had transported them to the bottom of the ocean; and that there they have been consolidated by various causes; but chiefly by subterranean or volcanic fires; and we are to imagine the expansive power of the same irresistible agent to have again elevated the strata from the bottom of the ocean; to have given them various states of induration, and to have thrown them into those differing degrees of inclination to the horizon which they now exhibit; simply raising them in some instances; dislocating and removing them from their old posture in others; and occasionally effecting their entire fusion. The unstratified substances are supposed to have been in the latter predicament, while the stratified bodies are regarded as having been only softened by heat, or penetrated by melted matter. And as present continents were formed from the disintegration and corrosion of prior rocks, so are they supposed to be gradually restoring their materials to the sea, from which new continents are hereafter to emerge, manifesting a series of changes similar to the past.

Though in the details of these theoretical views there is very much that is fantastic and improbable, it must be allowed that there is also much that is consistent with the known agency of bodies, and which is even directly borne out and verified by the actual result of experimental investigation. Indeed, the progress of modern chemistry has disburdened the Huttonian doctrines of some of their heaviest inconsistencies.

When more copious facts and evidences have been adduced, I shall beg leave to call attention to some of the chief elucidations of the Wernerian and Huttonian hypotheses; and then, and not till then, shall we be able to make up our minds respecting their relative value and merits. I shall, however, dwell upon them, not so much from any conviction of their intrinsic importance, as with the intention of shewing the chief, and indeed real value of these and similar disquisitions, that of awakening in the mind a desire of investigating nature and of collecting facts: for observations accumulate very slowly when unassisted by the influence of system—the observer never proceeds with so much ardour as when he theorizes, and every effort to verify or to disprove particular speculations necessarily leads to the evolution of new facts, and to the extension of the limits of useful knowledge. It is, therefore, the business of genuine philosophy rather to point out the imperfections, to expose the errors, and to restrain the presumptuousness of the theorist, than to attempt the entire extinction of a spirit which, however incomplete and insufficient the materials on which it has to work, must at least facilitate generalization, smooth the paths of knowledge, and render the approach to truth less rugged and tedious.

Having now attempted to bring before the reader a brief account of a few of the principal geological theories, with a view to give some insight into the objects of this branch of science, considered in the abstract, I trust I may recommend this pursuit, as embracing, in its secondary applications, a variety of useful and popular information.

In mining, in the search for coal, in the structure of canals and roads, in building, draining, and in the judicious search for and management of springs, the advantages of practical geology are incalculable. It has frequently happened that materials for roads have been transported at great expense from distant parts, when they might have been abundantly procured in the neighbourhood; in sinking wells, injudicious situations have often been pitched upon, and buildings erected at a distance from copious sources of water. In the fruitless search for metallic veins, millions have been expended upon the delusive promises of ignorant adventurers; and coal is frequently sought for in places, which even a slight knowledge of the subject indicates as hopeless.

The arrangement which I propose to adopt in the following pages is too simple and obvious to need any detailed explanation. We shall commence with an examination of the superior or uppermost strata, and more particularly notice that wonderful history of the devastation and destruction of a former order of things, which is exhibited by the various alluvial and diluvial matters that cover the uppermost of the secondary strata.

These secondary strata we shall then examine in their natural succession—the chalk, with its contents and accompaniments will claim much notice; and here, and in the superincumbent beds, we shall find brick-earth, potter's clay, and various other products applicable to the arts: here, too, we shall discover the seat of those subterraneous rivers, which, flowing from more elevated situations, make their appearance at different depths, and in different strata, constituting the various springs of hard and soft water about the metropolis.

The next substances that occur, are the varieties of freestone used in rough sculpture and building, such as those of Bath and Portland, with their various argillaceous concomitants; and to these succeed the red sandstone and marl strata, in which are our deposits of rock salt, and with which are associated the still more important formations of coal and iron-stone: the whole of these strata, covering a vast extent of country, lie in enormous cavities or basins bounded by that variety of marble, commonly called mountain limestone, in which, in Derbyshire, and several of the northern counties, are also various subterranean treasures, and whence, more especially, are derived the enormous supplies of lead which enrich the British market. The truly metalliferous formations, or those rocks and strata in which the veins of the great mining districts of England occur, will now be exposed to our view; and we ultimately arrive at granite and its associates, which form the great and primæval mountain chains of the world, and upon which, as far as our limited inquiries enable us to ascertain, all the other rocks are incumbent.

Having thus examined the strata of our globe in the order of their succession, from the surface downwards, we may proceed to the structure, position, contents, and theories of metallic veins; to a general account of the relative durability of rocks and mountains; and to an examination of the causes which are tending to their disintegration and decay:—connected with this subject is the nature and formation of soils, and some other topics, which may prove of general use and interest.

I shall conclude my remarks with some observations connected with the causes and effects of volcanic fires, with the phenomena of earthquakes and boiling fountains, and with some remarks relating to other limited phenomena, as far as they tend to elucidate or explain any mysteries and difficulties which we may have met with in our previous inquiries.

Hastily as we have now gone over the subjects of geological research, I shall consider my intention in this introductory section as amply attained, if I have shewn that it is no unworthy or unimportant branch of science; but that, on the contrary, it embraces enticing, useful, dignified, and even sublime materials of discussion and instruction.

It surely concerns us all to know something of the ground we tread upon, of the country we inhabit, and of the sources and natural associations of the infinitely varied products, with which the mineral world assuages our wants, increases our comforts, and multiplies the luxuries of life.

To the traveller, geology opens, as it were, a new creation: in connexion with geography, it discloses what may be termed the physiognomy of the earth; thus clothing a barren country with numerous objects of interest, and giving a new zest to those pleasing emotions of the mind with which we behold the fertile landscape and fruitful plain; and to those more exalted sensations which are created by the majestic features of a rocky and mountainous district.

Finally, in displaying to us, as it does, in characters most unequivocal, the great and awful revolutions which this earth has suffered, it gives rise to a salutary reminiscence of those which yet may come; it shews us upon what slight foundations the present order of things rests, and how trivial a change would suffice to obliterate all that now exists: thus inspiring the well-attempered mind, not with sorry fancies and idle fears, nor with that superstitious awe which sometimes results from gross ignorance, and sometimes from perverted knowledge, but with deep and unshaken admiration of that boundless wisdom which governs the revolutions of nature—which,

> Builds life on death, on change duration founds,
> And bids the eternal wheels to know their rounds.

PARALLEL ROADS OF LOCHABER.

SECTION II.

Modern Geology—Substances of which rocks are composed—Silica—Lime—Alumina—Magnesia—Succession of Strata—Superior, supermedial, medial, submedial, and inferior Rocks—Superficial Appearances of the Earth—Valleys.

Having noticed some of the leading subjects of geology, and briefly enumerated some of the hypotheses entertained by our precursors in this department of physico-chemical science, I shall proceed more particularly to explain its objects, as they are now pursued, and endeavour to sketch an outline of the study, as it exhibits itself at the present day.

Its first and leading object is to become practically acquainted with the present state of the Earth's external structure; for, excepting of its crust or rind, we know nothing; and all that has been suggested, either by theory or experiment, relating to its internal *composition*, its density, and the constitution of the entire mass, is mere surmise and guess-work—deductions hastily drawn from superficial observation, or unwarranted inferences from imperfect researches.

The present surface of our planet is composed of lapideous materials, the nature and composition of which it is the business of mineralogy and of chemistry to determine: not that the minutiæ of either of those studies need, of necessity, be gone into by the geologist, for the substances which thus present themselves are, comparatively, few in number and simple in their nature, and their external characters and intimate composition are soon learned; yet, if he would pursue his subject under every advantage, and extend his inquiries into its more refined departments, he must neither be a superficial mineralogist, nor an imperfect chemist. A knowledge of the crystalline forms, and general mechanical characters of substances, must often be called to the aid of his speculations; and he can frame no plausible theory without combining with such information a just, and even minute, acquaintance with the effects of heat and various solvents upon mineral masses, and upon the parts of which they consist.

Without these guides, therefore, he who aims at any thing beyond mere practical geology will infallibly go astray: they are lights essential to his successful progress; and the wanderings of those who would penetrate into the more secret parts of geology without them, are abundantly manifest to the intelligent reader, in most of those speculative writers, whose eloquence and dexterity in argument may mislead the unwary into an acquiescence in their reasonings, but which, when measured by less fallible standards, are found void of solidity and truth.

Siliceous, calcareous, and argillaceous substances, either pure or nearly so, and in a state of mixture, or loosely and indefinitely blended, rather than in strict chemical combination, constitute a very large relative proportion of those rocky masses, or scattered or comminuted substances, which form, or have formed, the most exterior constituents of our planet; and of these, considered in the abstract, the chemical and mineralogical history is soon told.

Under the name of *rock crystal*, or *quartz*, SILICA presents itself nearly pure; and in the varieties of flint, agate, calcedony, and siliceous sand, it is, by far, the predominating ingredient. Its most usual crystalline form is a six-sided prism, terminated by a six-sided pyramid; but its primitive form is an obtuse rhomboid, nearly approaching the cube. In specific gravity the pure varieties fluctuate a little on one side or other of 2.6. It cleaves with great difficulty; its common fracture is conchoidal. There are many varieties as to form and colour, which chemical mineralogists describe and distinguish; they are all hard enough to scratch glass. The leading *chemical* characters of silica are, extreme difficult fusibility; insolubility in water, and in nearly all acids, except under certain peculiar circumstances of recent precipitation, under which it readily dissolves in potassa and soda; it is also easily combined with those alkalies by fusion, such compound constituting the basis of glass, and where the alkali greatly predominates, being soluble in water. This solution is called, sometimes, *liquor of flints;* the acids decompose it, and throw down a finely-divided *hydrate of silica,* which is soluble, to a certain extent, in water; a fact of some importance in relation to our present subject, and accounting, in some measure, for the existence of silica in certain mineral waters, and more especially in those of the boiling fountains or geysers of Iceland, which deposit it in abundant incrustations. Calcedony, and some other minerals, are also occasionally referred to, as attesting the once fluid state of silica from a watery solvent: its crystalline forms may have originated from igneous fusion, but the existence of aquatic *confervæ,* often of their native colour, or discoloured by oxide of iron, and of mosses and lichens, in certain agates, renders fire, in many instances, an inadmissible agent. Upon these subjects, Dr. Mac Culloch's inquiries are extremely deserving notice*. Even the chrysalis of a moth is, it is said, extant in agate. One other chemical character of silica must not be overlooked, as bearing upon geological theory, which is, its affinity for other earths, either in igneous fusion, or aqueous solution. In the former way, it combines with lime and alumina, with magnesia, baryta, and strontia. Pottery and porcelain are alumino-siliceous compounds, with an occasional proportion of magnesia. Three parts of silica, two of magnesia, and one of alumina fuse into a glass; and we find several compound minerals of analogous constitution. Nor must the humid attractions of silica be overlooked, for when its alkaline solution is added to aqueous solutions of lime, baryta, or strontia, or to an alkaline solution of alumina, compound precipitates of the earths are the results, several of which have been particularly examined by Mr. Dalton. (System, p. 841.) It may be right to add, that silica is, probably, a binary compound of oxygen with a peculiar inflammable base, which has been called *silicon*, or *silicium*, and that it appears to contain about half its weight of oxygen; but no application of this subject to geology renders it necessary to dwell upon it, however interesting as a branch of chemical inquiry, and as shewing how great a proportion oxygen constitutes of the solid, as well as of the fluid, matter of our globe.

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* Geol. Trans.

Carbonate of Lime is a very predominant ingredient in rocks—marble, chalk, oolite, freestone, and all the purer varieties of limestone, are essentially composed of it, and these substances form strata of prodigious extent. It predominates in all the varieties of shell, coral, and madrepore: with other substances, but especially silica and alumina, and a little oxide of iron, it is found in lias, and several marls and clays. Calcareous spar and statuary marble may be selected as this substance in a very pure state. The former, when transparent, is highly doubly refractive, as we see in Iceland spar. Its crystalline forms are very various, but they all result from a *primary rhomboid*, the angles of which are 105° 5′ and 74° 5′. Exposed under ordinary circumstances to heat, it loses carbonic acid, and leaves quick lime, and by such an experiment its composition is shewn to be 28 lime + 22 carbonic acid, or *per cent.* 56 and 44: but if it be exposed to heat and pressure, so as to prevent all escape of gaseous matter, it then fuses, and retains its carbonic acid; a fact of no small importance as connected with certain theoretic considerations of the Huttonian school of geology. Carbonate of lime is easily recognised by its softness, and by the effervescence which it produces when a little dilute muriatic acid is dropped upon it; and as none of the other carbonates constitute mineral masses, this criterion is alone sufficient to distinguish it under such and several other circumstances. Or, the presence of lime in solution may be detected by oxalate and by carbonate of ammonia, which, added to muriate of lime, occasion precipitates of oxalate and of carbonate of lime; both these yield quicklime upon exposure to a sufficient red heat.

ALUMINA rarely occurs pure in nature, but it is very abundant in conjunction with other earths, and is present in all clays and *plastic* earthy compounds, on which it confers the property of exhaling an earthy odour when breathed upon. It is nearly infusible when pure; but, as has already been stated, it enters into combination with the other earths, so as to produce fusible compounds. When in a very comminuted state, it dissolves in the caustic fixed alkalies, and in most of the acids;—with potassa and sulphuric acid, it forms the characteristic octoedral crystals of common alum. Alumina has so strong an attraction for water as to retain it for some time, even at a red heat. In its pure and crystalline form, it constitutes the gem called *sapphire*, of which there are several coloured varieties.

MAGNESIA, like lime, forms a part of several compound minerals, most of which have a greenish colour, and a soapy feel. Mixed in the state of carbonate, with carbonate of lime, it is found in a sub-species of limestone, to which it imparts peculiar characters. It is insoluble in the alkaline solutions, but readily soluble in many of the acids; and its presence is announced by a precipitate of carbonate of magnesia, on adding carbonated fixed alkali to its solution: while, on the other hand, bi-carbonate of ammonia, which throws down lime, does not precipitate magnesia unless phosphate of soda be added; and upon this is founded an elegant method of detecting the presence of magnesia, devised by Dr. Wollaston. Now the different sands, clays, marls, and limestones of the upper strata, are composed of mixtures of the substances just enumerated, and they constitute, in chemical combination, and with a few unimportant additions, the principal components of the primary rocks.

The regular succession of the Earth's strata has been already partially referred to, as determined by the inquiries of some of the earlier geologists; and as the order of this succession, and the respective characters of the series, will occupy much of our attention, it may be right to explain it by a few preliminary observations. Let us suppose a traveller, for instance, departing from London and travelling westward towards North Wales; and let us direct his attention to the ground which he passes over:—he first traverses a tract of clay and sand, then he enters upon chalk, which is succeeded by calcareous freestone and a species of argillaceous limestone; then comes a zone of red sandy marl, and mines of coal and iron succeed, surrounded by limestone, and followed by slate and granite.

If, instead of proceeding westward, his route lie to the north, the same succession of strata, the same rocks and mineral masses, exactly in the same general order, will present themselves, and various opportunities will occur, to lead him to another important fact respecting these stratified beds, which is, that they are evidently disposed at an angle, and neither vertical nor parallel to the horizon; so that their edges may be observed successively to emerge from under each other. The term *outcrop* or *basset* of the strata is applied to the successive zones thus formed; and their inclination or dip is found subject to much variation.*

It is impossible to contemplate this arrangement without discerning the important secondary purposes to which it so efficiently contributes; for those strata which at one place are at impenetrable depths, are at another so brought to the surface, as to enable us to examine and obtain them and their contents; numerous useful products and mineral treasures are thus collected at, or comparatively near, the surface, with which we otherwise must have remained wholly unacquainted, or which could only have been procured by almost insurmountable labour and expense. Without such obliquity of stratification, there would have been no succession of soils. In the whole machinery of springs and rivers, and the apparatus that is kept in action for their duration, through the instrumentality of a system of curiously constructed hills and valleys, receiving their supply *occasionally* from the rains of heaven, but dispensing them *perpetually* in thousands of never-failing fountains," we see other important consequences of this arrangement of rocks. Waters, collected upon the hills and on high grounds, filter and flow through the softer and permeable layers, producing springs in the valleys, and feeding streams and rivers, instead of accumulating in marshes and swamps, as they would do, were the strata horizontal, or the surface plane.

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* When the edges of the inclined strata are uncovered and visible upon the surface, they are said to *rise to the day*, to *basset*, or *crop out*; and where horizontal strata happen to rest upon the edges of the inclined, they are said to be *in an unconformable, overlying position.* But we should endeavour to shut these provincial vulgarisms and foreign barbarities out of the language employed in scientific disquisitions, unless necessity pleads for their admission. For the same reason I would object to the anglicising Werner's phraseology, which only encumbers science "with an army of harsh and unwieldy words, poured in rather to conquer than assist the natives;" nor would I adopt the terms oryctognosie and geognosie, "merely because a foreign school has chosen to annex ridicule to the terms systematic mineralogy and geology."

Among the strata or formations of the vicinity of London, chalk forms a very conspicuous feature; but there are, lying upon it, a variety of clays and sands, and beds of gravel, which will claim our earliest notice. Beneath the chalk, another and a distinct series of sands and clays will be found to prevail, which are incumbent upon calcareous freestone and lias: to these succeed marls and sandstones deeply tinctured by red oxide of iron, and often containing detached masses, as it were, of rock-salt and alabaster. These may be considered as constituting one comprehensive and important subdivision of the strata. The next includes the coal deposits, and the sandstone and limestone with which they are more immediately associated, or upon which they are incumbent. The third subdivision is characterized by the prevalence of slaty or schistose rocks; and the fourth is confined to granitic aggregates, of which there are many sub-species.

We thus find the coal strata interposed between two great families of rocks, which, with Messrs. Conybeare and Phillips, we may call the *supermedial* and *submedial* orders*; coal and its associates are the *medial* order, and granites on the one hand, and alluvial and diluvial matters on the other, form the *inferior* and *superior* series. Using these terms, we lose sight of all theoretical distinctions—of primary, transition, and secondary formations.

The medial order of rocks, and all above them, are characterized by containing remains of vegetable and animal tribes; and these are sometimes in great profusion: but they are far from being indiscriminately scattered through the strata; on the contrary, "they are disposed as it were in families, each formation containing an association of species, peculiar in many instances to itself, widely differing from those of other formations, and accompanying it throughout its whole course; so that at two distinct points on the line of the same formation, we are sure of meeting the same general assemblage of fossil remains."

In the carboniferous limestone, for instance, forming, as we have said, a member of the medial series, we always find the same corals, encrinites, terebratulæ, &c., from whatever part of the world our specimen comes. In the chalks, too, there is an association of shells, echini, and so on, peculiar to it; but if we compare the relics in the mountain limestone with those of the chalk, we shall find that they, in all cases, are perfectly distinct; that there is not, even in any single instance, a remote resemblance or analogy between them. Even between contiguous beds, there are often, in this respect, very striking distinctions, and the whole subject is of so singular and problematical a nature, as to have attracted, in an especial manner, the attention of the geological theorist. We have, for instance, as the lowest crust of the globe, or as its *nucleus*, as some mechanical philosophers will have it, a compound crystalline rock, generally very hard and permanent, in which the most inquisitive eye has as yet traced no organic remains of either kingdom of nature, no rounded pebbles, or any relic or detritus of other rocks. Symptoms of disturbance, perhaps of fusion, it does, indeed, exhibit, as our inquiries will hereafter teach us. On this granitic foundation is reared a slaty structure; and in the rocks between it and the coal-formations, animal remains, characteristically different from any which now exist, begin to make their appearance, and become abundant in the carboniferous limestone. Rounded pebbles, and other proofs of the existence and destruction of former rocks, are also here met with; but, what is not a little remarkable, we find in the coal strata themselves, which thus repose on the coral limestone, scarcely a single shell or relic of the kind; but on the other hand, abundance of vegetable remains, all, I believe, of unknown species, but of genera often allied to plants that now inhabit tropical climes. In the magnesian limestone, resting upon the coal measures, marine remains are again frequent; but in the red marl, which next follows, scarcely a shell or plant of any kind occurs. In formations that intervene between the red marl and the superficial strata, that is, in the varieties of lias and freestone, in the ferruginous and chloritic sands, and in the chalk itself, we find peculiar corals and echini, the remains of testaceous and crustaceous animals, of marine oviparous quadrupeds, and of vertebral fishes, all of extinct species, but quite distinct from those which we found below the red marl, and often remarkably distinguished among themselves according to the individual strata which they occupy. Lastly, in the uppermost and superficial strata, we find shells, not, as in former cases, changed, petrified, or lapideous, but in such a state that, when washed and cleaned, they might pass for recent: some of these correspond to marine shells, and others, in other strata or beds, resemble our present fresh-water shells; whence the alternate inundation on certain spots of fresh and salt water has been inferred. In the most superficial and highest of these strata, we at last arrive at shells such as now exist, and then comes that great tell-tale of the deluge, the gravel in which we discover the remains of land quadrupeds of unknown genera, and of extinct species, and, commonly, the latter correspond to inhabitants of very different climates at present*.

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* See "Outlines of Geology of England and Wales," a work indispensable to the geological student, and which it is to be hoped will be completed, by the publication of the second part.

Such are some of the topics which this part of geology presents for consideration, and which shew us, that the earth is indeed "a book in which men may read strange matters." Though the existence of fossil remains must have been noticed from the earliest ages, the philosophical discussions to which they have given rise are of very modern date, and the merit of fixing the geologist's attention upon them, as recording certain revolutions of the globe, belongs exclusively to Cuvier.

Another important circumstance upon which I have only slightly touched, is the very frequent occurrence of rounded pebbles composed of fragments of the older rocks, which are abundant in the secondary strata. These pebbles prove the antecedent formation and consolidation of the rocks, of which they are the debris; and they also shew another curious fact in the history of stratification, which is, that where they occur, as they often do, in vertical beds, they must have acquired that verticality by the operation of some force which has thrown them out of their original horizontal position; for we cannot suppose it possible that any extensive accumulation of loose gravel can have taken place upon surfaces greatly inclined to the horizon.

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* For some curious speculations in reference to these remains, the reader may consult Mr. Ranking's Historical Researches on the Wars and Sports of the Monguls and Romans, and also his Historical Researches on the conquest of Peru and Mexico, &c., and several papers in the Quarterly Journal of Science.

Such beds of consolidated gravel are common in the red sandstone below the carboniferous series, in that series, in the lower strata of the superior red sandstone, in the sand below the chalk, and in the gravel immediately above it and below the London clay.

Now it is impossible to contemplate the collection of marine relics which are so abundant in many of the strata, and which are found upon the summits of some of the loftiest mountains of the world, without immediately coming to the conclusion, that our present land has not been merely transitorily covered by the waters of an inhabited ocean, but that it has actually been formed of materials collected through a series of ages in the bosom of an aqueous abyss; and one of the first problems we are called upon to solve, is the cause of the change of level in this ocean, and of the emersion of our present land. It is difficult to conceive any considerable change in the actual quantity of water, resulting either from its transmutation or decomposition; yet such causes must not be excluded as impossible. But the most obvious solution of the difficulty is founded upon the supposition that certain powerful agents have elevated our present continents, and at the same time depressed the bed of the ocean: what was once, therefore, the bottom of an antediluvian sea, now appears to be our habitable land; and perhaps the dry land of a very remote period of the world, may be the bottom of the present sea. This disruption and elevation of the strata is not by any means a mere gratuitous assumption, for independent of the verticality of loose gravel beds, and other highly inclined strata which must have been once horizontal, we have so many other instances of dislocations and heavings up of the strata among the old as well as among the newer rocks, as, in the opinion of some, to demonstrate to the utmost certainty the agency of an irresistible elevating force; but here the inquirer will perhaps stop to ask *what force* or *what power* in nature could have been adequate to such extraordinary and gigantic effects?—a question which must be answered by minute inquiry into the position of the strata, their associations, texture, and derangements, and by a comparison of these with powers and causes now active or subject to our control and investigation.

Another geological consideration, independent in a manner of the former, but of much interest, and of some difficulty, relates to the causes which have been active in producing the present *more superficial appearances* of the earth; in carving it out into valleys, and fitting it as it were for the order of things which now prevails.

Valleys are more or less extensive furrows of the surface, ramifying generally to a considerable lateral extent, and independent of secondary purposes, fulfilling that most essential one of draining the adjacent lands of their water, and carrying it in brooks and streamlets, which gradually unite to form rivers, and ultimately convey their contents into the ocean, of which, in fact, they constitute a series of ascending branches.

Now there are some valleys and river channels which appear to owe their origin to some great convulsion or catastrophe, which has torn asunder the rocks and strata, and left certain intervening chasms; but in by far the greater number of instances we have no evidence whatever of the activity of such agents, and every thing indicates a less sudden and violent, but yet an energetic, cause.

Valleys frequently intersect the strata which they traverse, in such a way as to leave no doubt of their subsequent formation to that of their bounding rocks, a phenomenon almost always observable, and sometimes within very narrow limits; as where in a mountainous country a rapid river cuts through a narrow defile; on these occasions we observe the same strata repeated upon each wall, as it were, of the valley, the soil or substratum of which consists of the lowest layer of the series. Now when we witness such appearances, and when among the pebbles, and sand, and fragments of the low-land we find comminuted portions of the surrounding rocks, when we discover a collection of such debris in the soil and bed of the river, we almost necessarily arrive at two conclusions: one, that the strata once were continuous; and the other, that the intersecting agent has been water; water, not flowing as it now does, quietly through the valleys, but constituting mighty and destructive torrents, which, while they have intersected, have at the same time, in many instances, denuded the strata; which sometimes working upon soft or muddy materials, have transported them to a distance, but which have also ground down the hardest substances, and aided by the gravel and debris thus formed and impetuously hurried along, have chiselled out furrows in the more indurated and primary rocks. Some have vainly imagined the present streams as adequate to the production of such effects; but he whose sight is not dimmed by hypothetical blindness, will see evidences of a more powerful agent, and will at once, and plausibly, fix upon the deluge. I purposely omit the proofs of such irresistible and extended currents for the present; but of their general agency, the instance of intersection and denudation to which I have alluded affords strong confirmation: for it sometimes happens that in insulated hills, in *outliers*, as geologists occasionally call them, we discover, although at a considerable distance from the chain with which they were once connected, some of the lower ranges of those strata, the upper ones having been washed away.

But although we find it necessary to refer, for satisfactory explanation of much that we now see, to that period when the earth "was covered with the deep as with a garment," and when "the waters stood above the mountains," it is by no means intended to exclude altogether the influence of later and partial inundations, of which we shall duly take notice, but which are manifestly inadequate agents to the production of the effects just mentioned. Hence the necessity of a distinction of the terms applicable to them; and the propriety of designating the water-worn fragments, and pebbles, and débris of all the rocks, by the term *diluvial* products, while we limit the term *alluvium* to the sandy and muddy collections of our present currents: these are seldom carried far; they form flats and deltas near the mouths of rivers, and accumulations of finely-divided matters in their beds; but of the comparatively gigantic force of diluvial currents ample testimonies are extant; and when we find pebbles which have obviously been thus transported for many miles, and even huge blocks which have suffered a corresponding transplantation and attrition, and lodged in valleys separated by lofty ranges of hills from the rocks whence they must have had their origin, we may not only form some idea of the force of the torrent, and the power of attrition of the substances impetuously hurried along by it, but we also read in such phenomena the most unequivocal evidence of the non-existence of many of the deepest valleys and most striking irregularities of surface which now exist, at the time that the boulders and pebbles were transported.

Several geological hypotheses, and the Huttonian theory in particular, affect to descry, in the agency of existing causes; the source of those effects which we have referred to extraordinary and occasionally acting forces: they have assumed the present rivers as the excavators of their own valleys, and ordinary volcanic fires as the indurators and elevators of strata from the bosom of the deep! they think that the washing down of finely-divided matter formed by the action of air and water upon the present surface, and the inroads of the ocean as manifested by the abrupt precipices and shingles of the beach, are sufficient evidence of the slow but sure destruction of the present order of things; but such actions are not only of very circumscribed extent, they are absolutely inefficient; and even if we draw unlimitedly upon *time*, as the theorists, in opposition to all chronological evidence, have done, their tendency is often the very reverse of that which they would substantiate. The fact is, that the wasting and wearing causes that now exist, are either too trifling to be taken into the account, or are counterbalanced by renovations and re-accumulations: in proof of this the barrows of the aboriginal Britons have been well adduced by Mr. Conybeare *, as retaining the pristine sharpness of their outline, after a lapse of little less, and probably more, than two decades of centuries: even the fosse that surrounds them is not filled up. " Causes, then, which in 2000 years have not, in any perceptible manner, affected these small tumuli, often scattered in very exposed situations upon the crests of our hills, can have exerted no very great influence on the mass of those hills in any assignable portion of time which even the imagination of a theorist can allow itself to conceive; and where circumstances are favourable to a greater degree of waste, still there is often a tendency to approach a maximum at which further waste will be checked; the abrupt cliff will at last become a gentle slope, and that slope become defended by its grassy coat of proof." Even the ocean itself throws up shingle banks and marsh lands, which check its further inroads. So that these supposed destructive powers, as they seem to the superficial observer, or to the biassed theorist, are soon found to neutralize themselves, and are certainly inadequate as general agents, though their occasional and local effects may, if not duly weighed and compared, mislead us in the estimate of their powers. Indeed, of accumulation rather than of decay, of growth rather than of wasting away, we have further remarkable illustration in the phenomena of submarine and subterranean forests of trees manifestly buried in their natural position, as on the coast of Lincolnshire, Pembrokeshire, and Lancashire, in the valley of the Thames near Purfleet, and elsewhere. We also have instances of the agglutination of sand into sandstone, on the north coast of Cornwall; of æstuaries filled up by alluvial debris, as in the Cornish stream-works; and many other attestations of the extension rather than the destruction of habitable surfaces.

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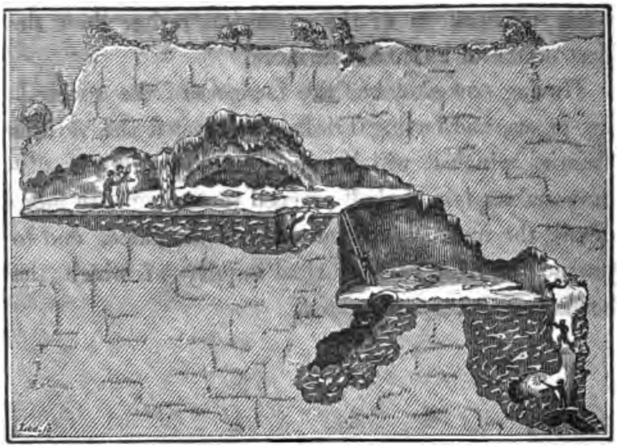
* Conybeare and Phillips: Outlines of Geology, page xxxii.

Having now sketched the business of the succeeding pages, and having briefly enumerated the various theories which it will be my object more fully to discuss and explain, I shall proceed to examine, in more detail, the most superficial strata of the globe, and to pursue the plan of geological inquiry of which the heads have been enumerated.



CAVERN OF GAILENREUTH IN FRANCONIA.

SECTION III.

Organic Remains peculiar to the Superior Strata.—Alternation of Fresh Water and Marine Shells—Parallel Roads of Lochaber.—Beds of Gravel.—Evidences of the Deluge.—Caverns containing the Remains of Quadrupeds.

Geology, like most other branches of study, must be considered in its practical and in its theoretical relations,—the first teaching us the relative positions, aspects, and qualities of those mineral aggregates, or rocks, which incrust the solid nucleus of our globe; and the second aiming at the discovery of the causes by which they have been produced, and investigating the events which have attended their deposition, and influenced their arrangements and characters.

In either view of the subject, geology presents an interesting field of inquiry; and when observation is blended with theory, when we are permitted to relieve the drudgery of collecting facts by incursions into its speculative regions, it opens a train of study and of research, to which few, from its variety and importance, can be inattentive or indifferent.

Whatever temptations may be held out, to deviate into the contrary path, and to amuse ourselves with the hypothetical flights of the numerous writers who have indulged in the speculative department of our subject, I propose, as far as may be, to confine myself here, to details almost exclusively of a practical nature; and if I sometimes venture to notice a theory, it will rather be to shew its failings and defects, than to offer any thing towards its embellishment and support: for it will be found, that in geology philosophers have too generally commenced their inquiries in the *study*, instead of in the *field*; that the most visionary and preposterous notions have been sanctioned by great names, and supported by most able controversialists; and that personal and acrimonious disputes have been suffered to ruffle the calm of philosophical society, which might have been speedily and amicably settled, by a reference, not to books of theorists recording opinion, but to the book of nature, establishing the fact. It is, I think, chiefly to the labours of modern and even contemporary geologists, that we owe the new and improved features which this branch of natural knowledge is acquiring. In their publications they have candidly recorded facts, which have shown the futility of much that was before thought sound argument and reckoned as brilliant reasoning; and there has therefore of late, in our hemisphere at least, been a proportionate and promising defalcation of those writers, who though, on some occasions, profound and ingenious, are not consistent with nature; or who have misemployed their abilities in assimilating facts to theory, instead of adjusting theory to facts. This revolution in English geology we chiefly owe to the establishment and publications of the Geological Society of London.

Geological theory, however, has, if properly estimated, many and important advantages; and many of the geological facts which have been established, as well as of our most valuable practical documents in illustration of the structure of the globe, or the stratification of particular districts, have, as before hinted, been derived from those whose curiosity has been incited to the inquiry by the stimulus of theoretical discussion. This indeed is universally the case in the progress of experimental science; and although there are still, among the philosophers, a few who are credulous in respect to all that *confirms* their preconceived opinions, but sceptical upon the facts that *oppose* them, the greater number have shown their willingness to exchange opinions for truth, and to eradicate error wherever it occurs, and however exalted the name or character by which it may have been planted.

As, then, I trust to find a sufficiency of facts, and those interesting and important, to form the basis of these outlines, I shall at once proceed to a brief account of the structure of the earth's surface; without stopping to inquire whether the globe we inhabit be an extinguished sun, or a mere pimple brushed from the face of that luminary by the tail of a comet: whether, as Kepler thought, we are parasitic animals, sporting upon the exterior of a huge leviathan, whose nostrils are volcanoes, and whose perspiration constitutes the ocean: or whether we may assume the mineralogical conjecture, that the earth is a monstrous crystal, the sides and cleavages of which represent the strata of its surface.

The strata of the globe (for notwithstanding the anathema with which Mr. Greenough opens his *Essays on Geology*, I shall be bold enough to use that term, under the presumption of its general intelligibility) appear, from the concurrent testimony of travellers, to present everywhere upon its surface certain analogies in respect to arrangement, and to succeed each other in a certain definite order. In the valleys, and we will assume the valley of the Thames, and the greater part of Essex, as an instance, we find gravel, pebbles, sand, and other matters resulting from detritus, mixed with more or less of vegetable remains, and constituting soils of various degrees of fertility and extent. The soil being removed, we find clay* and sand resting, probably everywhere, but evidently in many places upon chalk, and containing such a remarkable assemblage of organic remains, some of vegetable, and others of animal origin, as almost to baffle all conjectures as to whence they came, or under what circumstances they were brought together. The remains of sea animals are blended with those of the land, quadrupeds with fish, and fresh-water fish with those peculiar to the ocean. Animals of the land, the air, and the water, are assembled together in most unaccountable incongruity; fruits and leaves, hazle-nuts and pine-cones, are mixed with shark's teeth, crabs-claws, and oyster-shells. No less than five hundred varieties of fossil-fruit, mixed with sea-shells of various descriptions, have been found in the clay of Sheppey Island; and Mr. Trimmer's brick-fields at Brentford have yielded such a remarkable collection of sea-shells, shark's teeth, bones of the elephant, hippopotamus, ox and deer, together with fresh-water shells, as to impress us with the idea of the destruction or relics of a vast *menagerie*, in which animals of all denominations, and from all quarters of the globe, had been associated.

The clay formation of London and its vicinity is thrown into many picturesque irregularities, which are hidden by the buildings of the metropolis, but which are seen in Shooters Hill on the east, in the hills of Hampstead and Highgate on the north, and which contribute to the unrivalled beauty, in this line of prospect, of Richmond Hill in the west.

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* See Professor Buckland's description of the Plastic Clay, &c.—Geol. Trans. iv. 277.

In the Isle of Wight, at its west extremity, there is a section of the deposits superior to the chalk, attended however by some peculiarities to which I shall advert more in detail. They are especially remarkable for furnishing alternations of marine and fresh-water shells, from which it has been *conjectured* that the spot has been subjected to alternating inundations of the sea, and that, in some part of the intervening period, it has formed the bottom of a fresh-water lake*.

If we travel from London to Paris, we find, in the vicinity of that metropolis, facts equally irreconcilable with all commonly-adopted theory, and in most respects resembling those which the London *basin*, as it has been called, exhibits; for, if we suppose a large cup or concavity, scooped out of the chalk, imperfect in certain parts upon the sea-coast, where sections of its contents are exhibited, and filled up with sand, clay, organic relics, and alluvial products, we shall form a tolerably accurate notion of the general character of these districts.

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* In reference generally to the strata lying over the chalk, the reader may advantageously consult a perspicuous paper by Mr. Webster, Geol. Trans. II.

In the Paris *basin*, then, the first substance that occurs, lying immediately upon the chalk, is a layer of plastic clay fit for the manufacture of pottery; and upon this is a coarse limestone, with beds of sandstone and marle, enclosing marine petrifactions of various kinds, and many shells which still retain their pearly lustre. This stratum, is not quite continuous, for, in some places, its space is occupied by a siliceous limestone without any shells. We may, however, from its position and contents, call it the *lowest marine formation*. It is covered by a bed of gypsum, and by one of marle, enclosing a very remarkable series of organic remains, among which we may particularly notice petrified wood of the palm kind, and the relics of shells and of fishes apparently of fresh-water species. But, in the gypsum, are abundant remains of amphibious animals, and birds, including the bones of an extinct species varying in size from a sheep to a horse; there are also the bones of an unknown species of dog, fox, and ichneumon; the bones of the pelican, starling, and quail tribes: of the crocodile and tortoise; and of several varieties of fish allied to the present species that inhabit fresh-water.

Above these beds, the contents of which are thus miscellaneous and remarkable, and which are supposed to bear traces of *fresh-water* deposition, we find two beds of oyster-shells, one of which exactly resembles in the appearance of the shells, and in their disposition, those which are usually found in the ocean:

the greater number of them are whole, and have both valves; they alternate with sand and sandstone, and are covered by a deposit of limestone, containing fresh-water and land shells, nearly all of which belongto the genera now living in morasses: lastly, we come to the uppermost deposit, containing rounded stones and pebbles in a mixture of sand and clay, and abounding in the fossil remains of large trees, with the bones of elephants, oxen, deer, and other large animals *.

That low and level countries, in general, exhibit the same extraordinary records of devastation and change appears probable from various geological investigations that have been made in several parts of Europe, more especially in France and Germany; and in some districts of North America, which have been geologically explored, similar evidence of analogous changes is not wanting.

We may now revert to the strata lying upon the chalk in the Isle of Wight, in order to examine a little more particularly the circumstances under which they appear to have been deposited; and here the *verticality* of certain strata in the neighbourhood, which are usually horizontal, and which here exhibit traces of *having been horizontal,* are not among the least remarkable of the phenomena which this district exhibits. Headon Hill, situate at the west end of the Isle of Wight, in Alum Bay, is about four hundred feet high, and exhibits, towards the ocean, a curious and distinct section of its strata. Its base, as there seen, is a fine white sand, which may be traced into Totland and Colvill Bays on the north, and which, from its purity, is in great request among the manufacturers of flint-glass.

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* Vide Cuvier and Brongniart.

Upon this is a bed of gray clay, in which selenite and fossil-shells occur, and which supports the lower fresh-water formation of this district; that is, it has lying upon it a series of marles, some of which appear to consist of fragments of shells, with a few entire portions, from which their species have been ascertained. To this succeeds another stratum, containing sea-shells in great abundance and perfection, and separated by a bed of sand a few inches thick, from the upper fresh-water formation, composed of a marle, abounding in fresh-water shells, and covered by the alluvium, which forms the summit of the hill*.

Having now adverted to a few of the most remarkable facts relating to the uppermost strata of alluvial and diluvial matters, it may, perhaps, be expected that I should consider the various discussions to which they have given rise, and the opinions that have been maintained respecting the origin of such strange events as are thus presented to us at our very entrance upon the examination of the earth's strata.

It has been frequently argued, that the deluge is quite sufficient to explain all the remarkable assemblages of the remains of birds, beasts, fish, and vegetables, we have just had occasion to notice; and to account for the occurrence of the elephant, the crocodile, and other animals of that description in these northern parts of our hemisphere, it has been conceived that they were washed from tropical climates, and brought to us by a great and overwhelming current of water, traversing the globe in this direction; but these very theorists tell us of the formation of gravel: of the detrition and rounding down of the hardest substances in nature, by the same torrent, and yet the organic remains we have been looking at are for the most part so perfect, that they retain all those protuberances and indentations by which the skilful eye of the anatomist not only detects the part of the body to which the bones belong, but discerns, in the majority of cases, the genus and species of the animal, by the inspection of a single bone. Hence it has been inferred, but the inference, as we shall see, is not without most weighty objections, that these animals lived and dwelled upon the very spots in which we now find them. The bones of elephants and other very large animals, some approaching to, but others widely different from the species now in existence, have been met with in almost all countries where they have been diligently looked for, either in caverns peculiar to certain rocks, or in the alluvium of valleys, and generally, therefore, either in, or not far from the beds of rivers, and in islands as well as continents. Marsigli, in his *History of the Danube*, has described the remains of elephants, supposed to be those which Trajan carried with him in his expedition agains the Dacians. At the beginning of the last century, nearly a hundred tusks of elephants were dug up in an alluvial soil in Wirtemburg, some of which were upwards of ten feet long, and they were accompanied by the teeth and bones of several unknown animals, or extinct species.

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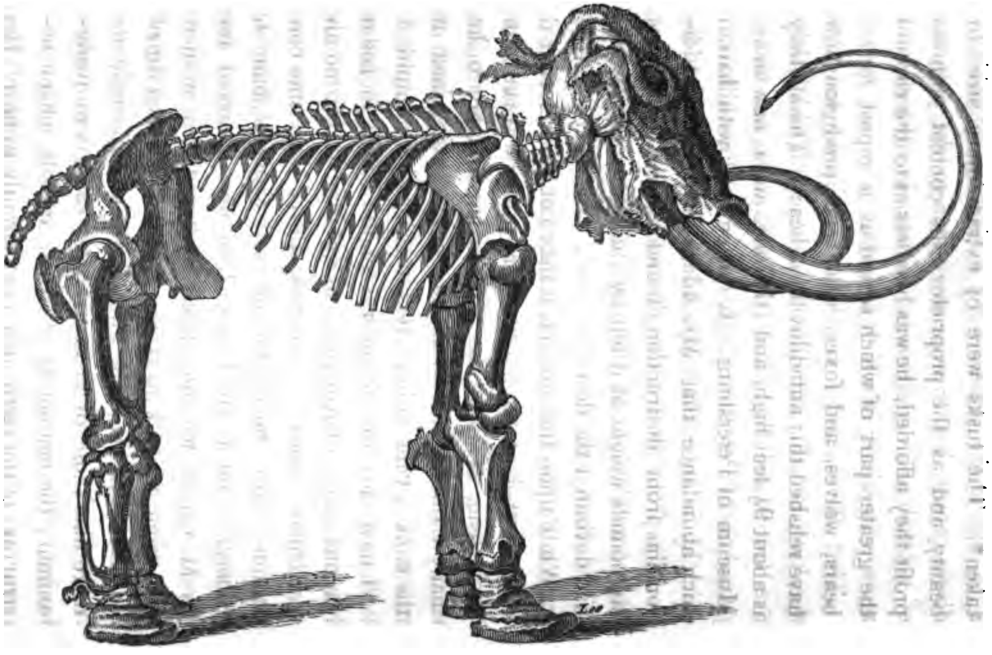
* Vide Webster, in Geol. Trans., and Sir H. Englefield's Description of the Isle of Wight.

In Italy, the country about Verona is famed as the repository of organic relics; bones of enormous magnitude have there been exhumated, and in such a perfect state, that we can scarcely suppose them to have travelled far, much less to have been submitted to the continuous operation of, or to ordinary transportation by water. No wonder that the ancients thought these were the remains of a giant race; that Pliny talks of human skeletons, twenty-four feet high; that Kircher describes the skeleton of Pallas, slain by Turnus, as higher than the walls of Rome; and that of one of the Cyclops, probably Polyphemus himself, as having been somewhere about 300 or 350 feet high. The same author, and others of great respectability, give us the measures of other colossal personages, and when we reflect, that the credulity and misinterpretation that are here so glaring are not the errors of the weak and illiterate, but of men of learning, and men of talents, of the best instructed by reading, by conversation, and by travel, of any in the ages in which they lived,—we cannot but be struck by the difference between the criterion of truth, as received in those ages, and at the present day; a diversity referable to divers causes, but to none more than to the progress of natural and experimental science, in modern, and more particularly in our own times.

That the animals, of whose remains we are now speaking, actually occupied the spots upon which they are found, and that their skeletons were not transported thither by the deluge, or by any post-diluvian debacle, is by some supposed to be rendered additionally probable, by the discovery of a rhinoceros and of an elephant in the north of Siberia, with part of the flesh and skin preserved. In regard to the former, Pallas observes that its foot alone was coated with more hair than that usually found upon the whole body of any living rhinoceros; and hence he suggests the probability of the animal having been a native of a colder clime than the torrid zone, and it is known that the rhinoceros in the North of India has more hair than the animal dwelling in the south of Africa. Again, in the year 1799, there was discovered in an iceberg, on the north shore of Siberia, a singular mass, which the fishermen observed for several winters without being able to ascertain what it was, when in 1803, in consequence of the thawing of the ice, it became evident that it was a large elephant-like animal, of which one of the tusks was protuberant. We are indebted to Mr. Stokes for an account of this animal, and for the drawing of the skeleton, from which the following wood-cut is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taken*. The tusks were of extraordinary size and beauty, and as the proprietor was content with the profit they afforded, he was heedless as to the carcass, the greater part of which served as a repast for the bears, wolves, and foxes, who seem prodigiously to have relished this antediluvian delicacy. The skeleton is about 9½ feet high, and 16½ long, and is now in the Museum of Petersburg. It was covered with hair in such abundance, that Mr. Adams, who rescued the remains from destruction, found no less than thirty-six pounds weight of it left by the beasts of prey that had devoured the flesh.

While upon this subject, it may not be irrelevant to observe, that almost all the ivory turner's work made in Russia, is from the Siberian fossil ivory tusks, many thousands of which are annually obtained on the banks of the larger rivers of that mighty empire.

I have adverted to the existence of fossil bones in various parts of America; those from the Ohio are particularly worthy notice, and were a long time confounded with the mammoth or fossil elephant of Siberia. But as Dr. Hunter long ago observed, and as M. Cuvier has more lately remarked, though there are strong resemblances, there are also marked differences in the skeleton, and the teeth especially are more like those of a carnivorous than graminivorous animal; the enamel is external, and the shape and structure of the teeth such as apparently to have fitted the animal for tearing up flesh, rather than masticating vegetables; they are also peculiarly tuberculated: hence Cuvier, referring this animal to a distinct genus, has called it, *Mastodonton*; he has, I believe, ascertained the existence of five or six species, some of which are found in the Old World.

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* Vide Vol. viii. of the Quarterly Journal, First Series, page 95.

I have adverted to the arguments in favour of the existence of these animals upon the spots in which they are now found, and have shewn reasons for supposing them there domiciliated; but to render such an opinion plausible, it must be proved that the climate of the northern parts of the world was once much warmer than at present, or that the animals themselves were endowed with very different temperaments, and we are far from being able to substantiate either of these requisites.

Against such an opinion it has also been argued, that very abundant remains of the same description have been discovered in islands, and even in some of the smaller isles of the Mediterranean, which would scarcely afford an elephant food for a week; and thus it has been supposed that the idea of these animals having been at home on these islets is preposterous and absurd: but then, again, it is manifestly not impossible, that when the islands in question were inhabited by these larger animals, they were parts of a continent; and it is not difficult, as I shall shew by-and-by, to urge strong grounds in support of such a theory.

Another circumstance has been adduced against the notion that these bones have been transported from other countries, which is their very general diffusion, and their abundance in various situations as well as climates; had they only occurred in countries conquered by the Macedonians, the Romans, and the Carthaginians, and were they the bones of the elephant only, and, further, did they present no peculiarities that stamp them as a more ancient and an extinct race, we might suppose, with the earlier speculators, that they were the bones of animals which had perished in the warfare of those nations; but taking the facts before us into the account, it is unsatisfactory to regard them as the victims of the restlessness and ambition of the human race, and they seem (as a modern writer has suggested) to belong to a period when man's dominion over the earth was limited and feeble; when perhaps the human race was confined to some favoured spot, and when the elephant, from his sagacity and strength, "was the chief master of the earth."

Among the extinct species of carnivorous animals, we must not forget to mention the bears, whose remains are found in the caves of Bareuth and the Hartz; the bones discovered by Mr. Whidby, in certain caverns in the limestone of Plymouth, probably belonged also to bears. Nor must we omit the singular associations of bones described by Mr. Buckland in a cave at Kirkdale, at Kirby Moorside in

Yorkshire, among which those of the hyæna, bear, wolf and fox, of the elephant, rhinoceros, hippopotamus, horse, deer, rabbit, and water rat, have already been discovered, presenting a truly curious assemblage, and importantly connected with various objects of geological inquiry. From the apparently gnawed condition of the bones, it has been concluded that the den was inhabited by hyænas, and that the other animal remains are the bones of their prey which had been dragged into the recesses of the den. Cuvier seems inclined to suppose, that the era of these animals was of a later date than that of the mammoth, and as there is no appearance of any sudden catastrophe having attended their sepulture, and as they are unaccompanied by the bones of marine animals, he also thinks that they lived and died in the caverns which now contain their remains. "Each cavern, it has been supposed, in the extensive chain of the Hartz and Hungarian mountains, was the den of a single despot, who sallied forth to prey upon the defenceless inhabitants of those woods which in later times, after men had become masters of the world, were called the Hyrcinian Forest."

Perhaps the most remarkable unknown species of fossil animal, is the elk of Ireland, to which I ought before to have adverted: it differs from our present elk, and from the rein-deer, in the size and conformation of its horns, the largest horns of living elks not being more than half the size of those found in a fossil state. But Mr. Weaver has rendered it probable that these remains are not ante-diluvian.

But if there be a difficulty, and a great one there is, in accounting in any plausible manner for the accumulations of bones and remains of animals of species now extinct, and in climates and countries apparently foreign to their habits and constitutions, there also are great difficulties in framing a theory to account for the alternations of salt and fresh water shells, and for those prodigious accumulations of pebbles and rounded fragments, constituting the beds of gravel that are incumbent upon the clay, and of which London and its vicinity presents us with such numerous and often interesting instances.

I have already adverted to the notion of the alternate inroads and retreats of the sea, combined with the occasional existence of fresh-water lakes, as having been assumed as the most easy method of accounting for the alternations of shells and deposits that have been discovered in the vicinity of Paris, and in the Isle of Wight; but this hypothesis is open to unbounded objections: the beds containing the different deposits closely resemble each other; the marine limestone and the fresh-water limestone, the marine clay and the fresh-water clay, and the marine grit and the fresh-water grit, present no mechanical or mineralogical difference. We may, therefore, perhaps, be sceptical, and there is much ground for scepticism, concerning the supposed accuracy of distinction between river and sea shells: the common test is the thickness, and an extremely delicate and thin shell is merely, as such, regarded as a fresh-water deposit, where it happens to fall in with hypothesis; but we well know, that sea-shells are by no means uniformly thick—nor are river-shells always thin and delicate. Mr. Greenough, therefore, is justified in doubting the possibility of the depositing menstruum having changed without any corresponding change in the deposited matters; and in discrediting the probability of a sea having retired before a lake, or a lake having been overwhelmed and annihilated by the inundation of the sea, without any trace of such catastrophe being any where visible, on the unconsolidated and unresisting materials which furnished the scene of action. But the *alternation* is the principal difficulty; for the existence of lakes, at levels and in situations which they now no longer occupy, is rendered probable by the characters and structure of the sides of hills and mountains that bound certain valleys; and more especially by the very remarkable appearances constituting what are termed the *parallel roads* of the mountains of Lochaber*. The very extraordinary aspect of these ridges is such as to arrest the attention of the most incurious spectator; and we cannot wonder that the solitary and poetical highlander should attribute to the ideal and gigantic beings of former days, a work, which, scorning the mimic efforts of the present ress, marches over the mountain and the valley, and holds an undeviating course over crags and torrents.

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* See the wood-cut at page 88.

These ridges or roads are seen in three strong lines on each side of a long, hollow, and deep valley, at a considerable elevation, and corresponding exactly with each other. Among the notions of their origin some are purely imaginary, others may be hypothetically supported. It has been supposed that they were made for the pleasure of certain kings of Scotland, who resided at Inverlochy Castle; and near these are the kettles of Fingal, in which with equal probability the royal personages are supposed to have dressed their venison. But although the magnificence of the object is such as to heat the imagination, and impose upon the judgment when considered as a work of art, we must look to some natural operation for the origin and cause of the phenomena, and among these none more plausible than the idea of the lake having successively occupied the different heights in the valley of these roads, and having formed them by the continual action of its waters, the edges and boundaries of which they represent: of such phenomena we shall offer more decided evidence.

The depositions of gravel so common in the London basin, and more especially upon the north of the metropolis, are very generally admitted to be of aqueous origin, and it has been supposed chiefly to have arisen from the wearing away and demolition of strata once lying above these alluvial matters, and especially from chalk flints rounded by the attrition of those waters which broke down and washed away the chalk that contained them; there is, however, the most distinct evidence of the more remote original of these beds, for they contain pebbles very unlike those flints now found in chalk, and they often present pieces of granite, quartz, and other matters, not only not existing in the neighbourhood, but very unlikely ever to have formed strata lying *above* our present chalk beds. Some more extensive, violent, or general cause, therefore, must have operated, as indeed is rendered evident by the inspection and situation of those larger and scarcer masses of rock, evidently rounded and transported, which are called *boulders*: these were probably much more abundant in former times than at present, having been removed partly for the purpose of building, and partly in clearing land for cultivation; but how they arrived in their present situations, often far distant from their evident sources, and not unfrequently with hills and valleys intervening, is a question which can only be answered by supposing what may perhaps be regarded an extraordinary and unwarrantable stretch of hypothesis;—namely, that these boulders were rolled into the places they now occupy, by some tremendous current and inundation, carrying sand, gravel, and boulders along with it, and which occurred before many of the hills and valleys that now lie between the sources of the boulders and their present situations were formed and excavated. That our present torrents could never have moved these mighty masses, considered independent of their origin and localities, is quite obvious; and hence some have been driven to the necessity of assuming a sudden disruption of the chaotic ocean, attended by earthquakes which rent the strata, and loosened the masses that we now find transferred to places far distant from their original homes; but the event of the deluge will amply suffice as the cause of these phenomena*.

Certain it is, that no powers now active can be considered as efficient for the production of our beds of gravel, and much less for the transportation of boulder stones, and that we *must* go back to a different aspect and state of the earth's surface from that which it now presents, and that we must suppose planes to have existed where the surface is now irregular. To illustrate this position by actual occurrences, we must suppose that the blocks of granite met with in the recesses of Mount Jura, and which if we consider them as derived from the source nearest at hand, must once have formed part of Mont Blanc, attest the non-existence of the Valley of the Rhone, and of the Lake of Geneva, at the time of their transportation—that the parasitic gravel and soil of the island of Malta, attest the non-existence of the Mediterranean at the time they were there deposited—that the blocks of primitive Norwegian rocks that are scattered over the north of Germany, Russia, and Holland, and occasionally met with on the east coast of England, announce the non-existence of the Baltic and German Sea while these blocks were in motion—and lastly, to come nearer home, the beds of pebbles and pieces of granite and quartz that constitute the diluvium deposited upon the little island of Staffa, could not have resulted from the flow of water in the present state of things, but must be referred to an antecedent period when Staffa formed part of Mull, or when the whole was perhaps a promontory of the main land. If we imagine, says Dr. Mac Culloch, the origin of the alluvial matter to be in Mull only, it still proves great changes; if we suppose, as some *have* supposed, that Staffa, as it now is, was lifted from the bottom of the ocean, with these pebbles and this alluvium lying upon it, we do not diminish our difficulty; we assume changes greater than the former, and adopt causes less consistent with the effect. Whether the forces that have operated have been gradual or rapid, slow or sudden, are questions which perhaps may be answered by an examination of the strata and their arrangements, and as we find *these* apparently undisturbed, it is not likely that the separation of Staffa from the adjacent islands should have been effected by any great dislocation, or earthquake, or Huttonian force emanating from below; it seems to have been more gradual and tranquil, and to have resulted from powers which have not shaken or disturbed the neighbouring parts, but yet have cut and carved away the intervening rocks. I must, however, beg that none of these remarks may be considered as having any reference to the origin of the island itself; but merely to the probable source of the matters which lie upon its basaltic strata.

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* See an important paper on the Evidences of the Deluge, by Professor Buckland, in the Geological Transactions, V. 506.

Reverting to the remains of quadrupeds, &c., which have been so assiduously and ably examined and described by Professor Buckland, it must be allowed that there are abundant difficulties in the way of any satisfactory theory respecting their origin and transportation. If we consider them as having lived and died in the caves, and on the spots where their remains now occur, we must presume, either that their habits and propensities were extremely different from those of the now existent species of the same tribes; or, what is yet less admissible, that the temperature of the northern regions was formerly correspondent with that of equatorial climates. Again, if we imagine the bones to have been transported thither by water-carriage, at the time of the deluge, how, it will be asked, can they have escaped attrition? and not this only, for they actually retain in perfection all the tuberosities and processes which enable the anatomist to recognise them. To get over this latter difficulty, it has been conceived that the bones were not transported along with the pebbles and gravel, but that they came safely packed and protected in their including carcasses, floating upon the surface of the waters, and were afterwards deposited safely upon the mud or gravel, where the flesh rotted and decomposed, and the bones remained uninjured. We know how readily this kind of transportation takes place, how rapid the carriage may be; and supposing the temperature not very high, we also know that many weeks might elapse before the carcass would sink. I shall not at present venture to give any opinion upon this question, but shall refer to the works of Professor Buckland, as the advocate of the one hypothesis, and to those of Mr. Granville Penn, who has defended the other.

If we now reflect upon the wonderful occurrences which even our most superficial strata record; upon the extinct species of quadrupeds, birds, and probably of vegetables, which they contain; and upon the enigma which the mere inspection of a gravel pebble calls upon us to solve,—we shall not be surprised at the occurrence of greater difficulties, when we descend into those strata of the earth, of an origin more remote and recondite; and I trust that seeing the insufficiency of theories, even when applied to the simplest cases, I have not judged amiss in passing lightly over the speculative part of geology, and limiting myself chiefly to its less excursive and entertaining, but more profitable practical details.

SANDSTONE ROCKS AT THE BACK OF THE ISLE OF WIGHT.

SECTION IV.

Supermedial Rocks.—Chalk.—Its aspects and varieties.—Green-sand.—Iron-sand.—Oolite.—Portland-stone.—Lias.—Fossils peculiar to these strata.

We may now proceed with our description of the strata, upon which the former materials are deposited: these are the *supermedial rocks* of Phillips and Conybeare, and include the varieties of chalk, green and ferruginous sand, oolite or freestone, lias, and red marle or new red sandstone.

Below the varieties of clay, the position and contents of which formed the subject of the last section, we find the chalk, which has already been stated to constitute the cavities or basins, in which the various alluvial matters are deposited. The ranges of chalk-hills in the south of England are very extensive, and the landscape which they constitute, peculiar for the smooth and rounded outline of its hills, their monotony of surface, and for the singular cup-shaped concavities and deep hollows in which their sides abound. The situation and extent of the chalk in England is best shewn by reference to coloured geological maps*. Salisbury Plain and Marlborough Downs form a centre, as it were, from which the chalk emanates in a north-east direction, through Buckingham, Bedford, and Cambridge shires, and terminates on the coast of Norfolk in one direction. Another branch, interrupted by the valley of the Humber, traverses Lincolnshire, terminating at Flamborough Head in Yorkshire. The extreme western point of the chalk is not far from Honiton in Devonshire, whence it branches off toward the south-east to the Isle of Purbeck, and again appears forming a ridge that crosses the Isle of Wight. Near Hungerford, in Berkshire, another range of chalk commences, and passes by Alton and Rochester to the coast of Kent, forming the cliffs between Folkstone and Deal. From near Alton, another branch passes off, and ends at the lofty promontory of Beachy Head on the Sussex coast.

In this chalk district there are some considerable elevations. Near Dunstable and Shaftesbury, for instance, it forms hills nearly 1000 feet above the level of the sea. Between Lewes in Sussex, and Alton in Hampshire, there are several similar elevations. Between Alton and Dover, the highest point is about 800 feet, and the Castle Hill is about 470 feet high. The chalk cliffs near Folkstone, and those near Lyme in Dorsetshire, are between 5 and 600 feet high.

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* Mr. Greenough's laborious map is particularly recommended for general reference.

Chalk, like the strata that lie upon it, abounds in organic remains, but they are of a different and more ancient character, exhibiting many new genera, and scarcely a single species quite identical with any that now exist. They are chiefly as follow :—

Remains of vertebral fish, such as teeth of a species of shark.

Among the testaceous mollusca, are ammonites and belemnites, generally in the lower strata only; a few spiral univalves and several bivalves.

Echini are very characteristic of chalk, and among them many species, and one genus, are peculiar to it. It also includes star-fish, encrini, many madrepores, alcyonia, and sponges.

The forms of sponges and of the alcyonia and echini are not uncommon in the flints; also casts of ammonites, and of nautili. These remains are not equally abundant in all parts of the chalk strata, nor are the strata themselves in all places similar. The upper beds of chalk abound in flints, which are usually disposed in regular horizontal layers, though there are cases, in which, from some derangement that appears to have occurred to the strata, the flints are nearly vertically arranged, as in the Isle of Wight, and on the Dorsetshire coast. But not the least remarkable fact, in respect to the perpendicular flints is, that they are generally splintery and broken, while those which are horizontal are in the usual state of rounded nodules. As the opposite coast of Dorsetshire exhibits a very similar arrangement, it is extremely probable that this chalk ridge has once been continuous, and that the shock or catastrophe that has broken it down, has also caused those inclinations, and that verticality of the strata once horizontal, that I have just adverted to. In the lower chalk strata, the flints become less abundant, and it frequently has a gray colour, and is *argillaceous*. These strata may be seen near Ryde in the Isle of Wight, and at Guildford and Dorking in Surrey, and the lime which such chalk affords derives certain peculiarities, as far as its use in making mortar is concerned, in consequence of its aluminous character. The greater part of the chalk-hills in Cambridgeshire are also composed of the lower or gray chalk, and they gradually pass into a kind of gray clay called *gault*, and into several varieties of argillaceous loam. In the neighbourhood of Deal, and in some parts of the Isle of Wight, the flint assumes the appearance of flattened or tabular masses, which are sometimes lost in a very thin edge. Near Freshwater, in the Isle of Wight, these tabular flints are arranged in diagonal layers, crossing each other in opposite directions.

Although the flinty chalk is not always found upon that without flint, it appears likely, from an examination of the neighbouring soils, that it has, at one time or other, everywhere existed; indeed, the enormous quantity of alluvial flints, and the deposits of rounded masses and nodules of chalk, which fill up the hollows in many parts of the chalk strata, are abundant indications of the destruction to which the chalk has been exposed,—a degradation to which its exterior situation and its softness render it peculiarly liable.

The cliffs at and about Brighton are particularly remarkable for the changes and devastations which they record. The town stands upon a bed of fragmented calcareous matter and flints, which, on the east, is seen resting upon shingles, consisting chiefly of flints, but mixed with rounded masses of granite, slate, and porphyry, cemented together by crystallized carbonate of lime, apparently derived from the solvent action of water upon the superincumbent chalk, thus forming a hard and durable breccia. Nodules of pyrites, and of crystalline carbonate of lime, are not uncommon in chalk. They are of a radiated texture, and the latter often unusually hard*.

Having stated thus much respecting the composition and contents of the chalk strata, I have little or nothing to add, relative to their origin, and that of their included fossils. The nature and characters of chalk seem to announce it as an aqueous deposit; but we must not be so bold as some geologists, who conclude that it is the detritus of coral reefs, and the dust of shells, originally derived from the antediluvian ocean. The existence of various organic remains announce the existence of those animals at the time of its deposit, but we never find in it the bones of quadrupeds, or of animals of existing species; and this circumstance appears to declare it of a date anterior to that of those superincumbent beds, which we examined in the last section. The origin of flints, their arrangement, the peculiarities which they occasionally exhibit, and the fossils they occasionally include, are subjects that entirely baffle all theory, and it would be mere waste of time to recite the hypotheses they have given rise to. Like the chalk, however, they bear marks of aqueous, rather than of igneous origin; they contain the same fossils, echini, sponges, and other substances found in the chalk; and what is curious, many of them are hollow, and contain powdered siliceous earth, provided they have no perforations; but if hollow and perforated, they are filled with chalk.

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* The chalk strata of Sussex are accurately and elaborately described in Mr. Mantell's "Fossils of the South Downs, &c."

The next beds that occur, in order of succession to the chalk, are several varieties of sand and clay; the former is often called *green sand*, from the fragments and particles of chlorite and green earth that it contains, and it is sometimes so compact and hard, as to be fit for a building material of no trivial durability. To what extent this formation accompanies the chalk is not quite obvious, but it occurs in many places on the western side of the chalk range extending from Dorsetshire into Yorkshire, and also upon the coasts of Dorset, Kent, and the Isle of Wight. This substance generally effervesces with acids, from the calcareous matter that it contains, and is abundant in organic remains; more especially those of the alcyonium, supposed to be a species of zoophite, and seen in a very characteristic manner at the back of the Isle of Wight, where large masses of this rock are lying upon the beach, having fallen in consequence of the washing away of the marly strata upon which they repose. This marle is of a bluish-black colour: in the Vale of Aylesbury in Bucks, and in that of the White Horse in Wilts, this stratum forms a tenacious clayey soil; and at Shotover Hill, Oxford, it abounds in oyster-shells, selenite, pyrites, and other fossils. Mr. Webster has particularly made us acquainted with the characters and peculiarities of this substance in the Isle of Wight. The sandstone strata that form the perpendicular rocks at the under cliff, lie upon a stratum of blue marle, which being soft and yielding, is occasionally washed away by land springs; the superincumbent rock of course falls, and to this cause we may attribute that ruined appearance which is so characteristic of the back of the island, and which, variegated with woods and corn-fields, gives a peculiar and highly picturesque character to that delightful spot. At Black Gang Chine, the washing away of the blue marle by the waters that filter from the higher land, and through the over-lying strata, is particularly well marked; and hence the cause of those *land slips* as they have been called, one of which took place to a great extent in 1799, and another about 1806.

The clays, gray chalk, and marles, which are common in many parts of the country that bound the chalk hills, scarcely admit of distinction into strata: they are often more or less intimately mixed with green sand, and contain beds, masses, and nodules of sandstone and limestone; these all appertain to the formation we are now speaking of, and lie upon those very extensive beds of sand, commonly called *ferruginous or iron sand*, of the characters and situation of which it will now be right to treat more at large.

This stratum must be distinguished from the sand lying *above* chalk, as that of Blackheath and of Bagshot. It is much more extensive, and constitutes a leading feature of many of those countries which contain or border upon chalk hills. It is accompanied by and often blended with some varieties of limestone; and frequently it scarcely is to be regarded as a distinct formation from *green sand*: perhaps its best character, its most marked and leading feature, is the quantity of oxide of iron that it occasionally contains, and which is so considerable in some parts of Kent and Sussex, as to have been formerly employed as a productive ore of iron. These ferruginous masses and veins are very abundant in and about Crowborough Heath; and the extensive district comprehended in a triangle, of which Dover, Beachy Head, and Alton, form the points, is chiefly composed of this kind of sandstone—here and there intermingled with other beds, but seen in characteristic masses on the coast near Hastings. Leith Hill, in Surrey, is also a good specimen of this formation; it rises to nearly 1000 feet above the level of the sea: at Bottom Head, on the coast of Yorkshire, it forms an elevation of nearly 1800 feet, which is perhaps the greatest height which it attains in England. This sandstone is seen with most of its peculiarities in the neighbourhood of Tunbridge Wells; and although in many places it is almost barren, or only covered with furze and heath, in others, where it contains embedded or intermixed clay and limestone, it constitutes a soil not unpropitious to the growth of several forest trees, and even bears very stately oaks. Near Woburn, in Bedfordshire, this sand is largely planted with firs; and there, as well as at Ryegate, in Surrey, it contains considerable beds of fuller's earth. The organic remains which it contains in greatest abundance are nautili and cornua ammonis. This formation may be traced with little interruption from the neighbourhood of Shaftesbury in Dorsetshire, to St. Neot's, in Huntingdonshire. It appears again on the east coast of Norfolk, reappears at Spilsby in Lincolnshire, and again in Yorkshire, where it reaches the north coast of that county, and covers much of its western district. In many places this sand is associated with and overlies several varieties of clay of different texture and composition, and often assuming a slaty aspect, and containing bituminous substances, pyrites, and in some places, as about Whitby, in Yorkshire, a considerable quantity of sulphate of alumina. On the south coast of England, as, for instance, in the Isle of Purbeck, this shale is abundantly bituminous, and forms what is called Kimmeridge coal. Organic remains are not rare in it; and in Wiltshire, it is associated with several varieties of limestone, in which they are extremely abundant. It is, however, doubtful whether these substance should not rather be referred to the oolite.

The Oolite Formation is extremely extensive, proceeding from Somersetshire to the banks of the Humber in Lincolnshire. Carbonate of lime is its leading ingredient, and several of its varieties are used as building materials, such as Bath, Purbeck, and Portland stone. Its texture, however, is such, that it is generally easily acted upon by the weather, and it is difficult to suggest any good criterion by which its relative durability may be judged of. It is sometimes supposed, that a comparative estimate of its value and permanency may be founded upon its absorbent powers in regard to water, but this is not always strictly true; that which abounds in shells and other organic remains is generally very subject to decay.

In the quarries in the isle of Portland, three distinct strata are visible: the uppermost, called by the quarry-men the *cap*, consists of fragmented and decomposing masses; it is immediately succeeded by horizontal seams, containing chert, flints, and some fine specimens of petrified wood; below it is the useful Portland stone. In this island, the beds dip to the south, and alternate with strata of bituminous shale. The limestones belonging to the oolite formation are of various degrees of granular fineness, and when made up of an agglutination of small rounded concretions, they are particularly called *roe-stone*.

In contact with the lower beds of the oolite, we find more compact limestone or *lias*, which may be considered as the lowest member of this formation; its different layers present various shades of white, gray, and blue, and it is, generally, speaking so argillaceous, as to exhale a strong earthy odour when breathed upon. To this ingredient, and to a portion of oxide of iron, the peculiarities of lime from this lias are referrible. It accompanies the great oolite formation, and is seen extending from Ilchester, in Somersetshire, by Bath and Gloucester across the centre of the kingdom, terminating near Lincoln. A little to the north of Gloucester, it forms eminences of more than 1000 feet high. These strata enclose a great variety of sea-shells and ammonites; and at Lyme, on the Dorset coast, they contain the skeletons and detached bones of a large animal, which has generally been regarded as the crocodile, but which Sir Everard Home has shewn not to be that animal, but a peculiar extinct species, which, from an analogy that exists between its spine and that of the Proteus, he has called Proteorachius*. As these strata contain such remains of amphibious animals, they make it probable, in the opinions of certain geologists, that fresh water and dry land existed previous to the formation or deposition of the oolitic strata, and consequently, of course, anterior to the chalk hills and their various superincumbent substances.

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* The remains of this animal (Ichthyosaurus) have been figured in several plates in the "Philosophical Transactions" from 1814 to 1820 inclusive. A more detailed account of the osteology of this genus, and a description of the plesiosaurus will be found in the fifth volume of the "Geological Transactions."

The crocodile is said to have been discovered in Lias, but the fact remains doubtful, as however true species of that animal occur in other beds associated with the oolitic series, there is no improbability in their occurring here also.

See Coneybeare and Phillips, part I. p. 266, where also will be found an arranged list of the other interesting organic remains that occur in the Lias.

RED SANDSTONE AT HAWTHORNDEN, NEAR EDINBURGH.

SECTION V.

Red Sandstone.—Gypsum.—Salt.—Coal.—Dikes and other peculiarities of the Coal Strata.—Origin of Coal.

We have now cleared our way to the great *red sandstone* formation, or to the *red marle* of modern geologists,—a substance of very extensive occurrence, and involving the history of some important deposits, more especially that of coal. I shall not stop here to explain the differences of opinion respecting the Wernerian phraseology applied to this rock, but it will be found that a very analogous substance occurs at greater depths, or among older rocks, and is then emphatically termed *old* red sandstone; the terms, new red sandstone, red marl, or the mere provincial phrase *red* *ground*, being applied to that formation which follows the oolite, and which we may now proceed to examine.

In the first place, in regard to situation, the red marle extends, without material interruption, from the east of Somersetshire to the northern bank of the Tees in Durham. The map shows the occurrence of coal beds in this district; the great coal formations, or coal basins as they are often called, being apparently deposited in the inferior or mountain limestone, and covered by, and alternating with red marle, or some of the substances with which it is directly associated. It may not be irrelevant to take a general view of the positions of this rock in the several coal counties, and to notice the other substances which form its constant or occasional accompaniments; and in doing this I shall make use of Mr. Phillips's abstract of the papers in the *Geological Transactions* relating to this formation.

Red sandstone generally forms a flat and low country, or where elevated into hills, their slopes are gentle, and their outline rounded. In the midland counties, it is traversed for a considerable length by the Severn; and the Ouse and Trent, streams tributary to the Humber, take a long course through its plains in the north. In the south-east part of Durham it exhibits strata of various colours, containing coal and gypsum. In Westmoreland it covers a considerable plain on the west of the range of mountains, of which Crossfell is the highest, and which is near the south-western extremity of the great Newcastle coal-field, The southern parts of Lancashire, the north of Shropshire, and the whole of the intervening county of Cheshire, are principally characterized by their plains of red marle; in Worcestershire it is a prevailing rock, as also in various parts of Derbyshire, Nottinghamshire, and Staffordshire. Without, however, further enumeration of the situations in which this rock occurs, a glance at a geological map will show its extent, and we may now shortly advert to its contents and embowelled treasures.

The texture of red sandstone, and I had almost said its *colour*, are very various; sometimes it is very soft and clayey, but in parts much more lapideous and indurated, and it is associated with beds of a peculiar conglomerate, consisting of nodules of different substances, cemented by marle or sand, and with a rock which we shall afterwards describe under the name of *amygdaloid*. It is generally unfit for architectural purposes, and from its softness has been in some places extensively excavated, as near Nottingham, where it is suspected that these caves may have formed the dwellings of the aboriginal Britons.

Deposits of *gypsum*, or *sulphate of lime*, are very characteristic of red marle, and this is a substance of no small importance as an article of trade; the larger masses are occasionally manufactured either in the turning lathe or by hand into vases and various ornaments, and are sometimes used in decorative architecture, of which the columns in the hall of

Keddlestone House in Derbyshire are fine specimens. The coarser varieties are employed in the potteries for making moulds, and some of the finer fibrous varieties are cut into beads, and broach stones of no mean beauty. When heated, it loses water, and crumbles into a white powder, well known as *plaster of Paris*, and employed for casts, and a variety of ornamental work. It has also been tried as a manure, but not with much success in this country, nor has any light been thrown upon the manner in which it operates as such. Sulphate of baryta, and sulphate of strontia, have also been found in this substance; but no organic remains have ever been discovered in it, although there are a few marine relics in the magnesian limestone below it.

Red marle is the last of the strata or formations, which is tolerably conformable as to position with those above it, and like them, nearly horizontal; the strata of the succeeding formations are said, in common geological language, to be *unconformably* placed with regard to the preceding, rising from under them at very various angles into lofty mountain chains, skirted by the red marle which occupies the extended plains at their base, "so that the appearance of the whole may be described by the figure of a sea composed of horizontal beds of red marle, &c., surrounding elevated islands consisting of rocks of the coal formation or carboniferous mountain limestone, old red sandstone, slate and granite, all variously and irregularly stratified."

In the red sandstone of Droitwich in Worcestershire, and at Northwich in Cheshire, are our most considerable beds of *salt*: at the former place, they are inundated, and form what are called brine springs *; at the latter, the solid salt is accessible, and has been excavated to a great extent both in width and depth †. At Droitwich the brine contains about one-fourth its weight of salt, and furnishes upwards of 16,000 tons annually. From this source alone the revenue derived an annual duty of 320,000*l.*; a fact, notwithstanding the partial advantages that accrue from it, greatly against the suspension of that equitable tax. At Northwich the quantity of solid salt annually raised exceeds 150,000 tons, about 16,000 of which are consumed at home, and 130 to 140,000 exported.

As the Cheshire salt deposits are below the level of the sea, it has been conceived that the ocean once covered the districts, and there let fall these enormous masses of muriate of soda, and that the clay, sandstone, and other substances, have resulted from the ruin of older rocks; but the salt is not such as would be obtained by the spontaneous evaporation of such water as our ocean now contains. Others regard these salt-pits as the bottoms of large cauldrons, in which sea-water has been boiled down by subterranean heat, and left the bed of salt like the earthy fur upon the bottom of a tea-kettle: I do not know that there is much choice between either of these hypotheses.

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* See an account of these springs, by L. Horner, Esq. Geol. Trans. II. 95.

† A most remarkable circumstance in the Northwich mine is the arrangement of the salt, giving rise to an appearance something like a mosaic roof and pavement, where it has been horizontally cut. The salt is compact, but it is arranged in round masses, five or six feet in diameter, not truly spherical, but each compressed by those that surround it, so as to have the shape of an irregular polyhedron.

In describing the *coal-fields* of England, I can only advert very generally to their arrangement and contents. The *Encyclopedia Britannica* contains two valuable articles upon this subject, and the details respecting the south-western coal district of England, published in the first volume of the second series of the *Geological Transactions*, by Messrs. Buckland and Conybeare, may be referred to as the best geological history extant of these important formations.

The great northern coal-district of England lies between the river Tees (which separates Durham from Yorkshire) and the Tweed, and the country slopes from Crossfell and Cheviots slowly towards the sea, the abrupt faces of the hills being upon their western side. The beds of which this coal-field consists partake of the general slope of the face of the country, reaching the surface on Crossfell, and gradually dipping towards the east, and away under the sea. At Sunderland they are covered by magnesian limestone, and they appear to lie in a basin of mountain limestone, abounding in veins of lead.

The strata of the coal-basin are coal, sandstone, shale, limestone, and basalt, and they abound in vegetable impressions and in fresh-water shells; among the former, the varieties of fern predominate; among the latter, bivalves like those of the fresh-water muscle. It may not be improper here briefly to notice the chemical varieties of coal that are presented to us in these districts, especially as relating to their economical applications.

The coal which is generally most esteemed is that of the northern districts, Northumberland, Durham, and Yorkshire; it abounds in bitumen, softens in the fire, swells, and throws out jets of flame; it coheres, and therefore burns hollow and requires poking; it furnishes cinders, though but little ash. On the other hand, most of the coal from the west of England blazes and burns briskly, being much more easily kindled than the other; it requires no poking, because it has no tendency to cake; it affords no cinders, and leaves a dusty white ash.

A third kind of coal called culm, or stone-coal, contains scarcely any bitumen, and abounds in earthy matter; it is of very difficult inflammability. Besides these, there are some other varieties, such as cannel-coal, splent-coal, &c.

There is one important circumstance observable in stratified countries in general, already adverted to, and more especially shown in the coal-beds, which is, that they were evidently deposited before many of those unevennesses which give rise to our present hills and dales were carved out upon the surface, and often where even a deep and extensive valley intervenes, the same strata running in the same direction, and at the same levels, are found continuous on both its sides; except in some particular cases, where the valley is very narrow and abrupt, and its sides perpendicular, and where it *appears* to have been formed by the dislocation and fracture of the ground, once continuous, in which it occurs.

In consequence of the peculiar arrangement of the coal strata, a section of them often gives the idea of a basin, or boat-shaped concavity, which has been successively filled with the various substances that occur in it; the seams of coal vary in number and in thickness, as well as in quality, and the upper seams are generally imperfect.

In consequence of the dip of the strata, it not unfrequently happens that we have an opportunity of examining and ascertaining the nature of the lowest seams, which, though deep and out of reach in one part of the coal-field, are superficial at another. This is shown at Cross-fell, where the crow-coal rises to day, which, in consequence of the inclination of the beds, is considered to be nearly 460 fathoms below the lowest of the Newcastle beds, a little to the east of that town.

The description of one coal formation applies, in general, to others; but there are certain circumstances which give peculiarities to some of our coal districts, among which the *iron-works* are deserving attention. The ore which is here worked is the *clay iron-stone*;

an ore poor in itself, but deriving value from the abundance of coal that attends it*.

Some writers have amused themselves with speculations respecting the exhaustion of our coal-mines, and have calculated the number of years, or centuries, that the stock on hand is likely to last. When, indeed, we reflect upon the vast importance of this species of fuel in a country dependent not merely for its prosperity, but even for its very existence, upon its manufactures and consequent commerce; when we remember its enormous and increasing consumption; when we consider that the metropolis only swallows up annually considerably more than a million of chaldrons, exclusively from the Tyne and Wear districts, it might appear that the apprehensions of some worthy persons upon this score were not altogether without foundation. It is however admitted, on the other hand, that the Newcastle mines only, are capable of continuing their supply for another thousand years; and if this reflection is insufficient to satisfy the disquieted minds of those who are still uneasy, they may console themselves with the reflection, that there are many other districts which have only been, as it were, begun upon, and probably numerous deposits of which we are as yet ignorant, but which will be searched for and found when wanted. Besides which, it may, I think, be calculated, that of every chaldron of coals consumed in our ordinary fires, about one-eighth part is lost in the character of soot, smoke, and other unburnt matters; so that in London only, upwards of 100,000 chaldrons of coals are thus dissipated and unprofitably applied to the contamination of our atmosphere, which smoke, by improved methods of combustion, might be turned to profitable account.

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* The *argillaceous ironstone* of mineralogists; it occurs both in layers and nodules; and although a poor ore of iron, very seldom yielding more than 30 per cent. of metal, it becomes, from its association with coal and limestone, (substances required for its reduction,) a most important natural product; it is the main source of the enormous quantities of iron manufactured in this country; and the history of the various difficulties which have been surmounted in completing the process of its reduction, presents an unrivalled picture of skill, ingenuity, and perseverance.

In speaking of the general arrangement of the coal strata, I have said nothing of the dislocations to which they are subject, in consequence of what are called *troubles*, or *slips*, and *dikes*; that is, the strata are cut through, broken off, and sometimes thrown up on one side and depressed on the other; the fissures and cracks thus produced are filled with broken stones and fragments of the strata, or with a hard species of rock called a dike, near which the coal is converted into a cinder, and from its cavities emits those tremendous torrents of inflammable gas, technically called *blowers*[*].

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[*] This variety of carburetted hydrogen constitutes the *fire-damp* of the mines; and when it has any where collected so as to constitute more than one-thirteenth of the volume of atmosphere, it becomes explosive whenever a flame is presented to it, and the source of such dreadful destruction, that the mind recoils from the recital. Formerly the miners,

To the probable origin of these faults, or dikes, I shall afterwards advert; they record one fact, namely, that the coal strata, subsequently to having assumed their present disposition and arrangement, have been subject to various disturbing causes, breaking their

in these dangerous situations, availed themselves of the light obtained by the collision of flint and steel, which, however, was by no means free from danger; the repeated accidents, and their alarming increase, induced Sir H. Davy to turn his mind to the subject, and he succeeded in discovering, not merely a perfect security from accident, but one which is easy of application, and very simple in construction.

His *Miner's Safety-lamp* consists of a common oil lamp, the flame of which is everywhere surrounded by wire-gauze, the apertures in which should never exceed one-twentieth of an inch square; the wire of which it is constructed may be from one-fortieth to one-sixtieth of an inch in diameter, and of iron or brass, but the former is preferable. Sir H. Davy also constructed some lamps of *twilled* iron gauze, containing sixteen wires in the warp and thirty in the weft. This material is nearly as permeable to the light and air as the ordinary gauze, and is much stronger, so that it will resist blows and pressure. An account of these lamps will be found in the first volume of the Journal of Science and the Arts, p. 1; and in Vol. II. p. 464; and a more detailed history of the invention is printed in the "Philosophical Transactions for 1816." The *principle* of *safety* consists in the cooling power of the wire in regard to flame. If a piece of wire-gauze, sufficiently fine, be held horizontally in the centre of an inflamed jet of carburetted hydrogen gas, it will cut off the upper half of the flame, while the lower half continues to burn; the gas passes through the wire, and the upper half may still be inflamed again in the usual way, after having been so far cooled by the intercepting wire as to be extinguished. So, in the wire cage of the lamp, the gas flame continues to burn, but it cannot make its escape through the wire in an inflamed state, so as to cause an explosion of the external atmosphere.

To the peculiar merits and singular importance of this discovery it is needless to advert; it ranks among the most valuable presents which philosophy has conferred upon the arts; it has already been advantageously employed in mines scarcely before accessible, and its use is daily extending.

continuity merely in some instances, but in others affecting the whole district, and throwing it for hundreds of acres together out of its original position.

Lastly, as to the sources and origin of coal. Upon these subjects geologists, as usual, have amply indulged their inventive faculties. Every thing tends to show the vegetable origin of coal, and a regular succession might be shown, commencing with wood, little changed, and ending with coal, in which all traces of organic texture are lost. Yet even in the most perfect coal we frequently find some relic, some trace of a vegetable, or some remains of fibrous texture that announces its ligneous origin. In the leaves that occur in Bovey coal, Mr. Hatchett, to whom we owe many important observations and experiments upon this subject, found resin and extractive matter; and what is more to the purpose, he found a substance having properties intermediate between resin and bitumen, which he has called retin-asphaltum, and therefore partaking partly of vegetable and partly of mineral characters; and more lately the same substance has been found in the principal coal-field of Staffordshire. Perhaps, therefore, antediluvian timber and peat bog may have been the parent of our coal strata; but then, how has its conversion been effected?—is it merely by the agency of water, a kind of decay and rotting down of the wood; or has fire been called into action, torrefying the vegetable matter?—and has the pressure under which this heat has operated prevented the escape of volatile matters, and caused them to assume the form of bitumen; and are those reservoirs of compressed carburetted hydrogen which I have mentioned as causing *blowers*, to be ascribed to such mode of formation? The discussion of these subjects might be prolonged, but it would end in nothing satisfactory. The theories that have been invented to account for our coal formations are full of weak and assailable points; the further we pursue them, the less do they satisfy us, and the more discordant do they seem with the phenomena they are intended to explain.

We should almost conclude, from the dogmatical air of some writers upon this subject, that they had seen the agents they speak of in active operation; that they had fathomed the depths of the globe, and measured its central heat; but if we compare our planet to an orange, and remember that we have not as yet nearly penetrated its rind; if we compare it to the pasteboard globe of the instrument-maker, and remember that we have scarcely peeled the paper from its surface,—these considerations should alone be sufficient to check the presumption of the theorist, and set bounds to the arrogance of hypothesis.

MOUNTAIN LIMESTONE IN DOVEDALE.

SECTION VI.

Mountain Limestone—Lead measures—Cross Veins—Toadstone—Aspect of Limestone districts—Old Red Sandstone—Grauwacke—Slate—Curvatures and Contortions of Strata.

THE TRANSITION LIMESTONE of the Wernerian school appears to be the same with that usually called MOUNTAIN LIMESTONE by English geologists. It forms many hilly, rocky, and mountainous districts, of singularly picturesque and romantic scenery in Britain; it is generally so compact in its texture as to break splintery—it takes a good polish—its usual colours are black, bluish, and reddish gray; it is often beautifully traversed by veins of calcareous spar, which give its surface in some instances a reticulated appearance; and it is in many parts characterized by its abundance of organic remains, more especially by those of marine animals, such as corallites and encrini. It is also rich in the metals, and, as already stated, is associated with our coal strata, forming as it were the ground or basis upon which they lie; its usual geological position being under the red marl and above the old red sandstone: the latter rock, however, is by no means always in its place, and instances are not wanting in which mountain limestone lies upon slate; but in that case it is very scanty in organic remains, and differs otherwise in appearance from the rock that lies upon the sandstone. I shall first briefly enumerate the principal districts in Britain characterized by this formation, and afterwards advert to its aspects and peculiarities as constituting mountain masses.

The great patch of limestone extending from the Tweed to the Tees, bounded by the coal measures on the east and by the Cheviot Hills on the west, is commonly called the *lead measures*, in consequence of the abundant veins of that metal by which it is traversed. Indeed the rocks which we are now about to examine acquire a considerable degree of importance and interest as being the principal seats of the useful metals, and as abounding in this country in lead, copper, tin, and some other metallic bodies.

The characters of the limestone of the lead measures are very variable; in some places it abounds in madreporites, encrinites, and other fossils, and is hard enough to receive a polish; in other places, from the prevalence of argillaceous matter, it acquires a bluish colour, softer texture, and loses its organic remains. In this great limestone district, the lead veins hitherto worked occupy a space of about fifteen miles N. and S., and twenty W. and E., and they run with little exception east and west. They present some peculiarities which are worthy of particular remark, although perfectly inexplicable, and to which I shall afterwards more explicitly allude. Among these, their varying dimensions, depending upon the nature of the beds they traverse, are particularly curious. In passing through the argillaceous strata, they become narrow, and even waste away into almost imperceptible threads, which again reunite in the limestone, thicken, and often bulge out into prolific bunches of ore; a vein, not more than two or three feet wide in the shale, and mixed with rocky matter, shall suddenly become pure in the limestone, and widen to between seventy and eighty feet.

Though these veins contain several varieties of lead ore, the sulphuret, or *galena*, is their only important product. The best ores yield about two-thirds their weight of pure lead, and often contain no inconsiderable portion of silver. We learn from Mr. Phillips, that between 1803 and 1810, the greatest quantity of lead shipped in any one year at Newcastle, was 10,352 tons—the least 3,910.

The average shipment at Stockton is about 3,000 tons annually. To give a general idea of the produce of these mines compared with others, it may be right to state that the whole of the lead-mines of Britain may be considered to afford an average annual produce of 45 to 50,000 tons.

This district, exclusive of its metallic veins, is penetrated and traversed by others, which, as they are only filled with lapideous substances, are of little interest except to geologists, and to them they have proved subjects of much discussion and some contention. These veins, which generally run N. and S., often disturb the parallelism of the strata; and, intersecting them, as well as the metallic veins, give rise to much confusion and disturbance. In the district we are now upon, there is an instance of the elevation of the strata to more than two fathoms upon the side of such a cross vein. The contents of these veins are very miscellaneous; and where the material they are filled with is much harder and more durable than the assailed strata, their course is often perceptible upon the weather-worn surface of the country which they traverse. Such is the cross vein in these lead-measures, called the Devil's Back-bone, forming a ridge that may be traced a considerable distance along the strata through which it passes.

The limestone district of Derbyshire presents us with so many points of interest and importance, that much more might be said upon it than our space here admits. I shall only touch upon a few of its leading features. Castleton is at its N. point, and it extends about twenty-five miles S. to Weaver-hill. Its breadth is very irregular, but, I believe, nowhere exceeds about twenty miles. Its eastern end forms the delightful and varied scenery of Matlock, so strangely counterpoised by the dull monotony of Buxton at its western edge. Its north-western extremity is celebrated for the wonders of the peak.

In accounting for the varied aspect of this district, we may be assisted by recollecting, first, that the strata of limestone differ considerably from each other, and that beds of another species of rock intervene, which is provincially called TOADSTONE, and that the respective edges of these strata come to the surface; and, secondly, that the whole country is there traversed by a great fault or dislocation of the strata.

Mr. Farey has described the Derby district as composed of four beds of limestone and three of intervening toadstone. The upper bed of limestone is in part bituminous, and contains nodules of chert arranged nearly as flints in chalk. It contains entrochites and various shells, often exhibited in relief upon its weather-worn surface. Beneath it the rock contains beds of magnesian lime, and of siliceous lime, or dunstone; and towards its lower parts are the beds of black marble, which receives a good polish, and is manufactured into various ornamental articles *. The lowest limestone stratum is that which forms the peak forest, the downs of Buxton and the Weaver-hills, and in it are several remarkable caverns, such as the Devil's-hole, Elden and Poole's hole, and many others. Here also we find at Castleton those curious nodules and masses of fluor-spar, celebrated for the manufacture of vases, and a variety of other beautiful ornamental articles, as also that very singular mineral product called *elastic bitumen;* and the caverns abound in splendid stalactites and stalagmites, whilst their waters acquire a petrifying power from carbonate of lime.

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* Mountain limestone is an excellent material for building, and many of its common varieties are sufficiently indurated to be cut into vases, chimney-pieces, and the like. Where they abound in corals, and other organic remains, these frequently add to their beauty. The black variety is sometimes known under the name of *Lucullite,* given to it in consequence of the admiration bestowed upon it by Lucius Lucullus. (*Vide Plinii Hist. Nat.* 36. 8.) It has long been admired, and is often tastefully manufactured and ornamented by etching upon its surface. It is found in Derbyshire, Sutherlandshire, and Galloway, and contains, according to Dr. John, the following ingredients:

Lime	53.38
Carbonic acid	41.50
Carbon	0.75
Magnesia, and oxide of Manganese	0.12
Oxide of iron	0.25
Silica	1.13
Sulphur	0.25
Potash, combinations of Muriatic and Sulphuric Acids, and Water	2.25

All these limestones are converted into a more or less pure *quick lime* by the operation of a red heat, and are thus often valuable as affording mantures, and for other purposes.

The toadstone of Derbyshire is sometimes considered as regularly stratified between the limestone beds, but upon this subject considerable doubts may be entertained, and at all events the beds, if such they be, are liable to many extraordinary irregularities. The toadstone never contains shells, nor organic remains, which are so abundant in the alternating limestone. Nodules of chalcedony and zeolite, globules of calcareous spar, and some other substances, are not uncommon in it; and however unsatisfactory or inadequate our theories are, in respect to this extraordinary substance, it must by all be allowed to bear the marks and characters of a distinct formation.

In the cave at Castleton it forms a large, irregularly-shaped column, which has all the appearance of common basalt, and occasionally it acquires a columnar fracture; so that for this, and various other reasons, I shall transfer the history of the Derby toadstone to that of those irregularly-occurring rocks that sometimes are found in primitive, and sometimes in secondary strata.

The veins in the limestone of Derbyshire contain lead, manganese, copper, and also ores of zinc and iron. The proper repository of the lead appears to be the limestone, though it also occurs in some other strata, and rarely in the toadstone, in which it is always in small quantities, and merely in strings, or very imperfect veins.

Near Bristol, the limestone hills rise from below the red sandstone, and are seen forming the edges of the coal-basin. In some places it is very bituminous, as on the Avon at Chepstow, and even exudes petroleum.

On the Welsh coast of the Bristol Channel we have another ridge of limestone, forming the basin, as it were, in which the great coal-field of S. Wales is situated. The hills that skirt Swansea Bay, and much of the delightful scenery of Neath and its neighbourhood, the sudden slope which is crowned by Knoll Castle, and the sinuosities of Pont-Neath-Vaughn, are characteristic of this formation; and again upon the banks of the Wye it constitutes scenery of a soft, but most romantic character. Upon the perpendicular and projecting precipices, lichens of various colours alternate with the gray surface of the uncovered rock. A variety of shrubs are showered by Nature's hand upon its more even, but still picturesque surface; ivy, and other creeping plants, issue in gay luxuriance from its crevices, and its steep sides are adorned by every variety of verdure. The charms of the valley of Matlock, of Dovedale, and indeed of much of the Derbyshire landscape, situated in the limestone glens, baffle all description; they have exercised the pencil of the painter and the pen of the poet, but all their addresses to the eye and to the imagination are cold and vapid, contrasted with nature's reality in these delightful spots.

I have formerly alluded to the occurrence of a red sandstone, beneath the red marle accompanying the coal and salt deposits. This is the *old* red sandstone of Wernerian geologists, and its situation upon the lowest secondary rocks appears to give it a title to that term. It often appears more as a conglomerate than a sandstone; that is, it is made up of coarse particles and pebbles, and ranges of it are sometimes seen following those of primitive rocks, where it is evidently composed of their débris. Like many other rocks, it derives its colour from oxide of iron. Geologists differ a good deal in their accounts of the position of this rock in England. One place I may mention as affording unequivocal specimens of it, namely, the N. coast of Somersetshire and Devonshire upon the Bristol channel, where it is seen recumbent upon slate, and even alternating in strata with that rock, and gradually passing into it. The red rock prevalent about Exeter, and that which occurs in the vicinity of Edinburgh, and which is seen in perfection at Hawthornden, have been referred by some geologists to this formation—the former probably does belong to it, but the latter strictly appertains to the red marl.

There occur in various parts of Britain a variety of sandstones, some approaching the nature of breccias and conglomerates, others slaty, and others almost exactly corresponding to the red marl in texture and appearance, which, when beneath the mountain limestone, and upon grauwacke or slate, are usually, and properly enough, called members of the old sandstone family, and in this way we may perspicuously dispose of them without entering into the pedigree of the old red and of the new red, which some geologists have descanted upon with such pertinacious prolixity. I may, however, here state, that sandstone does not always intervene between mountain limestone and slate; on the contrary, numerous instances might be adduced of limestone at once recumbent upon slate, in which case it is generally very scanty in fossil remains, and often passes, by a kind of insensible gradation, into the slaty rock. The dock-yard and neighbourhood of Plymouth furnish such specimens.

We here take leave of that series of rocks which Messrs. Phillips and Conybeare, in their excellent Outlines of Geology, have appropriately designated the *medial order*.

DERWENT-WATER.

The next substance we have to examine has received the uncouth and unmeaning name of *grauwacke*; it is a rock which has often been regarded as setting definition at defiance, and sometimes specimens not referable to any other classes, and substances of doubtful origin, have been indiscriminately considered as of this family. A rock with more or less of a slaty texture, but distinguished from slate by its less-perfect lamellar fracture, and above all by its embedded fragments, and being at the same time essentially argillaceous, appears to me to constitute legitimate grauwacke. If I found evident fragments of slate embedded in an homogeneous slate; or angular pieces of quartz; or of chlorite slate, in black slate; or here and there an imperfectly-rounded mass of any other substance, I should call such rock grauwacke. The mountainous part of Somersetshire included in its north-west district; the great slate formation of Cornwall; the ridge that follows the Malvern Hills,—these have sometimes been adduced as grauwacke, but they do not come within the definition I have proposed. We must resort to Cumberland for illustrative specimens of this rock, and to the scenery of the lakes for a notion of its mountainous aspect. There is something exquisitely beautiful in the mountains that environ the southern extremity of Derwentwater; their forms, tints, and general association and outline, are perfectly peculiar—they have not the craggy summits and fragmented precipices that belong to a true slaty texture, nor do they form these bold masses and blocks which announce mountain limestone to the eye of the distant observer —they shew an union of softness and grandeur which marks them as a distinct formation; and if there be a difficulty, which there often is, in deciding respecting hand-specimens, grauwacke may, in general, soon be recognised, where the forms of its hills can be traced.

CLAY-SLATE ON THE COAST OF NORTH WALES.

Associated with these rocks, and next in order of succession, are several varieties of *slate*, which, however, may, without any inconvenience or inconsistency, be referred to the great clay-slate formation, of which, in England, we have abundant and grand instances, especially in the northern and western parts, and which constitutes the greater portion of the mountainous district of North Wales. It is an abundant rock in Cumberland and Westmoreland, but is there so interwoven with the varieties of grauwacke, and has been so completely confounded with that rock in geological descriptions, that it is extremely difficult to draw the line of distinction between them, or to say where the one ends and the other begins. The cluster of hills, however, of which Skiddaw forms the highest elevation, may probably be referred to genuine clay-slate; and in Devonshire and Cornwall the granitic range which traverses the promontory like a backbone, beginning on Dartmoor, and ending at the Land's-end, has slate overlying it on both sides. All the magnificent scenery of Falmouth, Fowey, Looe, Tintagell, and of other places too numerous to particularize, upon the north as well as the south side of Cornwall, derives its grandeur and charms from the various assemblages of slaty headlands, promontories, creeks, and islands. Sometimes its strata jet out in bold fantastic forms upon the ocean, and sometimes gradually shelve away into gentle slopes; their verdure is usually scanty and uncertain, but here and there a clayey soil finds a resting-place, and cherishes patches of shrubs interspersed with trees of loftier growth, and attracting the traveller's attention by the sterile and fragmented surface which generally surrounds these insular spots of vegetation. The beauties of the coast of Cornwall are singularly contrasted by the barren exterior of its central road and great mining district, where we scarcely find a blade of grass to relieve the black and sombre hues of the ground, but where heaps of rubbish, that once was rich in embowelled treasures, give a gloomy irregularity to the surface, and where the ponderous heaving of machinery raises subterranean rivers to a level not their own, and turning them into new channels, enables the miner to arrive at those riches, which, but for the inventive genius of Watt, would have remained in inaccessible obscurity.

I have adverted to the confusion which has prevailed in the definitions of grauwacke, and have endeavoured, as far as concerns ourselves, to attain perspicuity by limiting the extent of this term. Of its unlimited application, I can give no better instance than is furnished by the county of Cornwall, where all the slate has been by some geologists, and those of experience and observation, classed under that embarrassing and perplexing term: while others have entirely denied the existence of even a solitary cabinet specimen in the whole district. Truth, however, lies between these extremes, and there are, in several parts of Cornwall, but more especially about the neck of the Lizard Promontory, certain strata, or, as they rather should be called, beds of a rock, to which even a sceptic as to its existence elsewhere cannot deny the name: it is a rock which is slaty in its composition, and slaty in its texture, but which, from the fragments and particles distinctly embedded in the main mass, is legitimately allied to the enigmatical family of the grauwackes; while the slate of Tintagell and of Camelford is a distinctly unadulterated and admirably defined clay-slate, and esteemed of an excellent quality as a roofing material.

To the rocks which we have just considered, and to some others that will hereafter demand attention, belongs a remarkable feature, of which Cornwall furnishes some admirable and unrivalled instances, and which is truly perplexing to every person who looks at and examines the phenomenon unblinded by the dust of books and the fog of theory. The slate is remarkably *contorted* in some places; its strata are waved and curved for greater or less extent, and sometimes an entire bed affects a serpentine irregularity, which gradually merges into a straight line above and below. These contortions of the Cornish slate are sometimes independent of any other kind of rock—sometimes they are *apparently* caused by veins of *elvan*, to use a term of the country—by veins of a distinct species of rock which is of a porphyritic character, and which invades the slate, as it were, from below, bending it into a thousand shapes, or sometimes merely dislocating and giving a new inclination to its strata, *seeming* as if, in the one instance, it had acted upon the soft, yielding, and unconsolidated matter that surrounds it; in the other, as if it had violently protruded itself into the already-hardened mass. On another occasion, this phenomenon will come more decidedly under our notice; the concomitant effects must be studied, as well as the main ones, and thence we must endeavour to deduce an efficient cause;—at the same time, I must here remark, lest I should be thought to adopt the principles of those very theories which I am verbally contending with, that such contortions, although best observed in the slaty rocks, are not peculiar to them; that they are not characteristic of the transition-series of the Wernerians, but that they may be seen, by those who choose to see them, in gneiss, in mica-slate, in clay-slate, grauwacke, limestone, basalt, sandstone, and shale—nay, even in the newest of the new rocks, as at Purbeck, in Dorsetshire, in the freestone; in the chalk at Handfast Point, in the Isle of Wight; in that of Montmartre, at Paris; in the pulverulent and coaly matter, on the road between Edinburgh and Leith; and Mr. Greenough informs us, that he found the same waving lines in sandstone, *now forming*, at Port Dinnleyn in Carnarvonshire.

These curves are not less varied in their forms than in their dimensions; they are sometimes only a few inches in extent, and the whole may be included in a hand-specimen; at other times they extend many feet and yards, and even sometimes for many miles. Saussure, in his Travels in the Alps, speaking of the shape of these contortions, compares them to the letters Z and X, exhibiting their angular and zigzag forms; to the letter C, shewing their tendency to circular flexure; and on the road from Chamouny to Geneva, a perpendicular surface of limestone exhibits the strata in one part bent into arches, and producing, by their association with the bendings in another part, a form not unlike the letter S.

These curvatures are regarded by Dr. Hutton and Mr. Playfair to have originated in the elevation of the strata once horizontal, while in a flexible and ductile state, by a force acting upon them from below upwards: owing to gravity and the resistance of the mass, this direction became oblique, and the lateral force caused contortion; but this view, although ingenious, and often consistently applicable to the appearances, is sometimes, and indeed often, so at variance with them, that it cannot be plausibly entertained as a general cause: among the leading militant instances, we may advert to the existence of curved *upon* horizontal strata. Near Malvern, limestone, much contorted, rests upon strata quite horizontal. Mr. Greenough adduces, as another similar instance, the singular stratification of Mont Righi, in which highly-curved limestone rests upon strata preserving perfect horizontality: how happened it, then, that a force adequate to the flexion of one part of the limestone, elevated more than 7000 feet above the sea, should not have affected the inferior beds? A case still more opposed, and indeed, if admitted in the abstract, fatal, to Dr. Hutton's theory, may be seen upon the west side of Loch Lomond, where veins of contorted slate traverse strata which are not contorted, nor even disturbed. But if the Huttonian geologists are unsatisfactory upon this point, the Wernerians are still more so; indeed, quite unintelligible. The contortion of the masses, they tell us, is the result of crystallization!

The authors of these hypotheses to account for the bendings and inflexions of strata, these contortions to which rocks are liable, have too frequently bent and distorted the facts to fit them to their own peculiar notions; and they have too often, evidently, attempted to explain appearances referable to several causes, by the assumption of one power.

If we consider the strata in which they occur to have been once in fusion, in solution, or in diffusion, the relative times of consolidation, the warping and the shrinking of one substance, as compared with others, may have had its share in producing these mysterious irregularities.

If slate be a deposit of finely-divided matter once mechanically diffused through water, its irregularities may obviously have arisen from some irregular agitation of the water during its deposition, like those undulations in the sand upon the sea-shore, which are obviously occasioned by the waves.

I have now, probably, said enough of the curvatures of strata, to excite attention to the subject, and more than enough to shew how inadequate are the theories which have been assumed to account for them. If, by saying more, I could throw more light upon the subject, I would proceed; but the further we investigate the facts, the more incongruous and inexplicable would they appear: I am, indeed, already apprehensive that I may sometimes fatigue the attention, by asking it for opinions rather than things; but geological hypotheses are apt to run into rank luxuriance, if not occasionally trimmed; and though great authority and exalted talent has sanctioned much that I have presumed to doubt and attempted to disprove, it must be remembered, that many of the opinions which we have been called upon to combat and to reject were advanced in the feeblest infancy of the science; and from the known candour and scientific integrity of many of those with whom they originated, there cannot be a shadow of doubt that, if opportunity offered, they would frequently recall, modify, or resign them. It is, at all events, our particular province and duty to direct our humble endeavours towards establishing, as far as may be, a strong line of demarcation between facts and opinions; to take care that genuine science, which aims at the interpretation of nature, is not checked by the crudities of modern scholastics—that the roses are not smothered by brambles.

Cornwall has been cited as furnishing upon its coasts favourable specimens of lowland clay-slate scenery; its mountainous aspect is seen to great perfection on the western side of Wales, where Snowdon, Plynlimmon, and Cader Idris, with many of their respectable associates, present the peaked summits, the dark and narrow valleys, the terrific precipices, and the fragmented slopes that peculiarly belong to this formation.

Slate is often traversed by veins rich in the metals, and abundant in fine specimens of various crystallized minerals. It is matter of doubt whether it ever contains organic remains, though the impressions of some bivalve shells are said to have been found in it. I am, however, rather inclined to believe that these impressions are either in grauwacke slate, or in that which borders upon and passes into limestone, and that genuine clay-slate is destitute of shells—a fact which appears opposed to its imaginary aqueous origin, and which has given rise to the presumption that the ocean was uninhabited by living beings at the time that this great deposit was produced.

Not the least important fact in the history of the rocks which have now been considered, is their gradual, and often insensible, transition, as it were, into each other; for it furnishes us with a strong argument against many of those speculations into which some geologists have entered respecting their origin and formation. The gradual migration of chalk into clays and sandstone, and of these into oolitic deposits; of oolite into lias, and of this again into limestone, is visible in many hand-specimens, and there are equally well-marked instances of the transition of clay-slate into red sandstone on the one hand, and on the other into mountain limestone and into grauwacke: so that those rigid lines of demarcation, and sudden transitions, which the student might be led to expect from the perusal of certain systematic geological writers, are not in general to be met with in nature.

Another circumstance by which some of the rocks we have just considered are distinguished from others, and more especially from those formerly described, is the defalcation of organic relics both in quantity and perfection. The shells and corals, so abundant in the mountain limestone, are not blended with any kind of bones, nor are there any vegetable remains; and in the underlying sandy and schistose formations a solitary shell now and then occurs, whilst in the micaceous slates, and the rocks belonging to the granitic family, which next claims attention, there is neither shell nor coral, nor any impression or semblance of any thing that has ever appertained to the organized kingdoms of nature. The gradual transitions of one kind of rock into others on the one hand, and their sudden and abrupt lines of demarcation on the other; their verticality in one place, and their horizontality in others; their occasional resemblances, and frequent dissimilarities, are a few of the circumstances which will lead the cautious and unprejudiced observer to distrust those accumulations of hypotheses which have sometimes been dignified by the title of geological theories, but which, in assigning opposite virtues to the same subject, are alike at variance with nature and with themselves—they are systems which might pass for the inventions of those ages "when sound philosophy had not as yet alighted on the earth, nor taught man that he is but the humble minister and interpreter of nature *."

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* I have said above that organic remains are never found in the inferior order of rocks; and that this constitutes one remarkable peculiarity of the series. Some exceptions to such a statement are mentioned by some of the earlier writers on geology, but they were manifestly mistaken as to the true source of their specimens in some cases, and in others they describe deceptive appearances. The only observation of this kind to which any importance can be attached, has been made by Dr. Mac Culloch, who describes a bed of limestone containing organic remains, as lying under gneiss, in one of the Hebrides: but the contortions of the gneiss strata, of which he has given a sketch, are so remarkable, and their flexures so considerable, that they are often bent back upon themselves, and it is consequently very possible, that rocks which, as to position, are actually superior, may appear in places to be inferior. At all events, there appear no grounds for supposing any exceptions to exist as to the correctness of the general statement given above, respecting the absolute non-existence of the slightest traces of any kind of organic relics in the inferior order of rocks, that is, mica-slate, gneiss, granite, and their associates.

VARIETIES OF GRANITE.

SECTION VII.

Granite; its varieties and aspects.—Gneiss.—Mica-slate.—Syenite—Porphyry.—Marble.—Serpentine.—Quartz Rock.—Granite Tors.—Decomposing Granite.—Association of Rocks in Glentilt.—Theories.—Rocks at the Fall of Fyers.

We have now arrived at the primitive formations of the Wernerians, at those strata, or rocks, upon which all others appear to rest, and which, towering up through the superincumbent substances, form the exposed peaks and loftiest summits of the principal mountain-chains of the world*. Whether these rocks are to be regarded as original formations, upon which the other stratified materials have been successively deposited in that order of arrangement which we have enumerated; or whether the stratified rocks are to be considered, with the Huttonians, as *primary*, and the granitic and other masses that we are about to examine, as having been subsequently elevated by the expansive force of subterraneous heat, are questions that have eagerly engaged the contending geological schools, and to which too much importance has often been assigned. As we proceed in the examination of these substances, we shall notice such of their characters as have especially given rise to the igneous and

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* The highest mountains in Britain are composed of granite and its associates; but these are mere trifling protuberances upon the earth's face, when compared with the exceeding heights of the Alpine chain, or the yet more elevated mountains of South America, and of the

Asiatic continent, which consist of the same materials. Ben Nevis, the loftiest of the British mountains, is situated in the south of Inverness-shire, and is four thousand three hundred and seventy feet high. Cairngorm, in the same county, is four thousand and fifty feet high. Mont Blanc in Switzerland has it peak elevated fifteen thousand six hundred feet above the level of the sea; it is the highest mountain of Europe; Chimboraso, the highest summit of the Andes, is twenty thousand two hundred and eighty feet above the sea's level.

The highest known mountains in the world, are those of Thibet, constituting the Himalayan chain. They are alluded to by Colonel Kirkpatrick in his history of Nepaul, and an extended and interesting account of them has been published by Mr. Colebrooke in the Asiatic Researches, Vol. XII.

Of this chain, the highest peak, covered with eternal snow, is called Dwawala-giri, or White-mountain; it is the Mont Blanc of the Indian Alps, and rises to the astonishing altitude of twenty-six thousand four hundred and sixty-two feet above the level of the plains of Gorakh'pûr; or upon the lowest computation, twenty-six thousand eight hundred and sixty-two feet above the level of the ocean. This is about six thousand feet higher than Chimboraso, eleven thousand feet higher than Mont Blanc, and twenty-two thousand feet higher than the most elevated peak of the British dominions.

aqueous sects; but, as heretofore, I shall consider hypotheses and theories as very subordinate objects.

Under the term *granitic formation*, I include, not merely granite, properly so called, but the substances into which it merges, either from the predominance of one or other of its ingredients, from the loss of one or other of them, or from the occasional addition of some new mineral; and I shall also include, in this division of rocks, those substances which are their occasional accompaniments: such as serpentine, marble, and primary conglomerates; rocks always, and exclusively, associated with the granitic series, and unknown amongst those formations in which organic remains are to be found.

Under the generic term *granite*, we include all crystalline aggregates of quartz, felspar, and mica *.

Quartz, or siliceous earth, known in its crystalline form under the name of rock-crystal, has already been defined.

Felspar is a compound body, of which siliceous and argillaceous earths are predominant ingredients: it generally contains a little lime and potash, and is often coloured by minute portions of oxide of iron *. Sometimes it is found crystallized, when it assumes the form of four and six-sided prisms bevelled on the extremities; its usual colours are red, white, and gray. It is softer than quartz, but harder than glass, and is characteristically marked by fusibility before the blowpipe.

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* Some have regarded granite as a congeries of crystals of mica, felspar, and quartz, *accidentally* blended and united: the inspection, however, of the rock, would rather lead us to infer that all its materials have been together in fusion; for we find in some granites the quartz impressed by the crystals of felspar, and in others the felspar receives impression from the quartz. Dr. Hutton has looked upon this as *demonstrating* the igneous fusion of granite, for, (says Mr. Playfair) "had the materials been dissolved in water, one kind of crystal ought not to impress another, but each enjoy its own peculiar shape." This, however, I do not hold to be sound argument.

Felspar is a very important ingredient in many kinds of pottery; and the substance used by the Chinese, under the name of *petuntz*, is probably of a similar nature. The decomposing felspar of Cornwall is abundantly employed in the English porcelain manufactories, and as it contains no iron, it retains its perfect whiteness. According to Mr. Wedgwood, it consists of

60	Alumine,
20	Silex,
20	Moisture and loss.

There are some beautiful varieties of felspar em-

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* In a fine specimen of pale flesh-red felspar, from the Alps, crystallized in the form of the oblique four-sided prism, I found the following constituent parts:

Silex . . .	68.00
Alumine . .	20.00
Potash . . .	8.30
Lime	2.00
Oxide of iron . .	0.50
	99.00
Loss	1
	100.00

ployed in ornamental jewellery, such as the green and blue of Siberia and America; the foliated, pearly, or resplendent felspar, called adularia and moonstone; and the felspar of the island of St. Paul, upon the coast of Labrador, distinguished by the property of reflecting very beautiful colours when the light falls upon it in certain directions. Felspar is an important component of several other rocks, besides granite.

Mica, the third of the essential ingredients of granite, is a well-marked compound mineral, consisting principally of argillaceous and siliceous earths, with a little magnesia and oxide of iron. Its texture is lamellar, and it is easily split into thin, flexible, elastic, and transparent plates. It is so soft as readily to yield to the nail: it is sometimes met with crystallised in four and six-sided plates and prisms. Its usual colours are shades of brown, and gray; sometimes it is red, and sometimes black. In some parts of Siberia mica is copiously quarried, and is employed as a substitute for glass in windows and lanterns. It has been thus used in Russian ships of war, where it has the advantage of not being shattered, like glass, by the discharge of artillery. The extreme tenuity of the plates into which it may be divided, and their elasticity, renders it very useful for the enclosure of objects to be submitted to microscopic inspection.

The characters of granite depend much upon the perfection or prevalence of one or other of these ingredients. Their aggregation in the crystalline form is, in some specimens, distinct and well defined, in others, imperfect, forming what are usually called fine and coarse grained granite; large crystals of felspar sometimes prevail, and from these the leading hue of the granite is derived; or where mica abounds, the rock acquires a lamellar and slaty fracture, and is then called *gneiss;* where the felspar is very sparingly disseminated, or altogether wanting, or where garnets supply its place, granite is said to pass into *mica-slate,* and this again into *quartz-rock,* by the partial or entire disappearance of the mica.

Hornblende is an alumino-siliceous mineral, containing magnesia, and abundant in black oxide of iron; it forms prismatic crystals, which are sometimes blended with granite, and sometimes with felspar only, constituting syenitic granite and *Syenite,* and where crystals of felspar are embedded in massive felspar, quartz and hornblende being occasionally superadded, but not predominant, the rock is called *porphyritic,* or *porphyry.* It is right here to advert to syenitic and porphyritic rocks, as associates of the granitic formation, though we shall find that there also exists a very close resemblance between them and some of the varieties of greenstone, included in the family of trap rocks. I have also mentioned marble and serpentine, as accompanying granite. The former is here distinguished as *primitive,* in opposition to the mountain limestone, which abounds in organic remains, and lies above the slate; the primitive is granularly foliated in its texture, and without any trace of fossil animals or vegetables; it is celebrated as a material for sculpture, when white and fine-grained, and is, in all cases, a valuable ornamental substance.

The most esteemed varieties are perfectly white, and free from veins; somewhat translucent, and susceptible of a good polish. These marbles are imported for ornamental purposes, especially for those of the sculptor. Nearly all the sublime works of the Grecian artists were sculptured in the marble from the Isle of Paros in the Archipelago. Next in point of estimation is that of Carrara, in Italy*. Of the coloured varieties, that of the Isle of Tiree, is extremely beautiful; it is of a pale red, spotted with green hornblende. Marble is found in several parts of Scotland, and in some places of characteristic beauty, and alternating within small limits, with other rocks. In Inverary park, it may be seen in contact with mica slate and porphyry. Serpentine and marble are sometimes blended together, and they then form a valuable compound for ornamental purposes. In the splendid serpentine of Anglesey, patches of marble are found, which much enhance its beauty. A very remarkable marble quarry is that of Icolmkil, or Iona, "that illustrious island, whence savage clans and roving barbarians derived the benefit of knowledge, and the blessings of religion." Syenitic rocks constitute its leading feature, but at the south-west point of the island is a bed of marble about forty feet wide, bounded by vertical walls of hornblende rocks *. Near it is a mass of hornstone, and above the whole protrudes an immense vein of granite, surrounded by the marble, but from which it has been loosened, so as just to admit a person to pass between the two walls. That they have once been in contact, is proved by the granitic protuberances having correspondent indentations in the marble, and *vice versa.*

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* White marble is quarried in different parts of the Alps. Near the summit of Mount Cenis, it is found fine grained and micaceous. There are quarries in the Vallais, and upon the Italian side of the Simplon, and in the hills surrounding the Alpine extremity of Lago Maggiore. Hence, is obtained the beautiful marble of which the Cathedral of Milan is built, and likewise that intended for the completion of the triumphal arch, commenced by Napoleon at the northern entrance of that Capital. In some places it contains interspersed hornblende.

Serpentine is a rock, concerning the characters and

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* The marble is of the species called *dolomite,* distinguished from the true primary marble or granular limestone, by the tardy effervescence excited by pouring muriatic acid upon it, and by its containing magnesia; it is also finer grained, and its fracture more splintery than that of common marble. The dolomite of Iona yielded to Mr. Tennant,

Carbonic acid	48.00
Lime	31.12
Magnesia	17.06
Insoluble matter	4.00

Phil. Trans., 1799.

The dolomite of the Apennines yielded to Klaproth,

Carbonate of lime	65
Carbonate of magnesia	35

Beiträge. B. 4. S. 215.

SERPENTINE AND MICA SLATE IN CORNWALL.

relations of which geologists are somewhat at variance. Hornblende, or schiller-spar*, and felspar, appear to be essential to its constitution, and perhaps also talc; and these three substances are sometimes distinctly visible, like the three components of granite; while, at others, the rock is so fine-grained as to be nearly homogeneous; its variety of colours, whence its name, recommends it as an ornamental material, but it is too soft to admit of much polish. The bright-green varieties, interspersed with white marble, form the *verde antique*, to which some of the serpentine of Anglesey bears a resemblance; and those varieties which are comparatively hard, and brilliant in their colours, are called *noble serpentine* *. Talc, which I have mentioned as a component of serpentine, is lamellar; but its lamina, unlike those of mica, are not elastic, and it has the soft soapy feel of a magnesian fossil. In composition it differs little from the steatite †, which is

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* *Schiller stone*, or *schiller spar*, is a term from the Germans, implying glistening or changeable spar: it is one of the varieties of *diallage* of the French authors; it is a silico-ferruginous fossil, containing

44 Silex,
24 Iron,
18 Alumina,
12 Magnesia;

its colour is dark green; its usual lusture is semi-metalic, varying according to its position, in regard to incident light.

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* Of *noble serpentine*, the following analysis has been given by Dr. John.

Silica	-	-	42.50
Magnesia	-	-	38.63
Lime	-	-	0.25
Alumina	-	-	1.20
Oxide of iron		-	1.50
Oxide of manganese			0.62
Oxide of chrome		-	0.25
Water	-	-	15.20
			99.95

The following is the analysis of *common serpentine*, by the same chemist.

Silica	-	-	31.50
Magnesia	-	-	47.25
Alumina	-	-	3.00
Lime	-	-	0.50
Iron	-	-	5.50
Oxide of manganese		-	1.50
Water	-	-	10.50
			99.75

Vide Chemische Untersuchunge. Th. 11. s. 208, 94.

† *Steatite* is a substance of different tints of grey and green, and from its very singular unctuous feel, has been called soap-stone. It is somewhat abundant in the serpentine of Cornwall, one of the masses of which is called the soapy rock; it was here carefully collected for the porcelain

found pervading serpentine in veins, and which, in many parts of the Lizard serpentine district in Cornwall, is accompanied by veins of a rock sometimes looking like the massive felspar, and at others becoming porphyritic, or even assuming the characters of granite. These are very curious facts, and it requires some forbearance to pass them over merely as such, without considering the theoretical views to which they lead.

I can hardly be induced to regard marble, serpentine, porphyry, or even syenite, as distinct formations. Sometimes they appear as beds or detached masses, varying in magnitude and extent; at others they look like modifications of some other rock. Quartz rock, too, which is said to form entire mountains, as in Jura, in Wicklow, and elsewhere, and which are characterized by their conical form and insulated appearance, is seldom free from mica, and often may be traced by regular gradation into mica-slate, and this into gneiss

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works of Swansea, in which it formed a very important ingredient. It also occurs in the serpentine of Banff. Varieties of this substance are the nephritic stone, or jade, and the axe-stone, employed by the natives of the South-Sea Islands for making cutting instruments. According to Klaproth, Cornish steatite consists of

Silica - -	45.00
Magnesia - -	24.75
Alumina - -	9.25
Iron - - -	1.00
Potash - -	0.75
Water and loss -	18.00
	98.75

Vide Klaproth's Beiträge, V. Band, S. 24.

and granite. But I throw out these observations, not with the intent of speculating upon them, but merely to simplify the history of primitive rocks, and to shew that the occasional recession or addition of one ingredient may give the whole mass a new character, mineralogically speaking, without entitling it to rank as a new formation, geologically considered.

Having, therefore, pointed out the composition of these rocks, as far as necessary to their definition, it remains to notice their aspects as mountain masses, to examine the circumstances that attend their junctions and alternations, and lastly, to ascertain how far the received theories of their formation are consistent with the appearances which they present, and upon which the Wernerians and Huttonians must be regarded as mainly differing.

The largest granite tract of England is that of Devonshire and Cornwall, where its sides are covered by slate, but where it rises in several places to the surface, and also forms the rocky promontory at the Land's End. There is here nothing either picturesque or sublime belonging to the granite formation. Dartmoor appears the head-quarters of dreariness and desolation, forming a large mountain tract of nearly 80,000 acres in extent, strewed with granite boulders, and fragments of rocks, and appearing to set cultivation at defiance.

This granitic district is nowhere of any considerable elevation; its highest point is the hill called Brown

Willey, near Bodmin, which is about 1360 feet above the ocean's level.

The peculiarities of the West-of-England granite are best seen at the Land's End, where a large patch of it protrudes in a wedge-shaped promontory upon the coast; it appears formed of fragments and masses placed upon each other in the rudest disorder, and sometimes in fantastic piles and insulated blocks, which, though arising from the peculiar manner in which the rock is decomposed and dislodged by the weather, have been mistaken for monuments of ancient heroes, and for druidical remains.

These *Tors*, as they are called, have been described by Dr. Mac Culloch in the *Geological Transactions*, and some of them are depicted in the engravings annexed to his paper. One, called the Cheese-wring, at Liskeard, consists of five blocks, of which the upper are larger than the lower, the whole pile being about fifteen feet high. The stones composing this, and other similar piles, suffer by the action of the weather most rapidly upon their edges and angles, which gradually become rounded, until the blocks begin to totter upon each other, and ultimately fall. This tendency of square blocks to become spheroidical, and which has sometimes been mistaken for the effect of friction, explains some of the mysteries formerly adverted to respecting granitic boulders, and shews that attrition by torrents, and transportation by streams, are not always essential to their rounded appearance. The celebrated logging-stone is also noticed in Dr. Mac Culloch's communication. It exhibits the tendency of this kind of granite to cuboidal separation, and although seventeen feet long, thirty-two and a half in circumference, and weighing sixty-five tons, may be moved by the force of a few pounds, and visibly vibrates when blown upon by a western gale.

Though granite is in general a very durable rock, and though the permanence of the lofty peaks of the Alps, and other great granitic chains of mountains, is such as to have enabled them to weather those storms that have carried away and disintegrated much of the softer materials of other, and probably of superincumbent strata, yet there are some varieties of granite subject to moulder down, and that even with no inconsiderable rapidity. De Luc talks of the friable granite of the Hercynian forest, and Saussure describes the mouldering down of that in the Alps. The waters of the Arve are rendered milky by the pulverulent felspar that comes from the Aiguilles de Chamouny, and other points that border the Mer-de-Glace. The road across Dartmoor, from Ashburton to Chagford, traverses in one place such loosely-compacted granite as to resemble a bed of gravel. The granite of the Carglaise mine near St. Austle, in Cornwall, is so soft and pulverulent, that the excavation might be mistaken for a chalk-pit; and in the same vicinity, the immense quantities of white porcelain-earth, as it is called, is of similar origin, and seems derived from the perishable nature of the felspar, which, giving way, suffers the quartz and mica to fall out. To what the extreme proneness of some kinds of granite to suffer decay, while others are as remarkably permanent, is to be attributed, does not seem quite clear; but if I mistake not, Sir H. Davy, in his geological lectures delivered in the Royal Institution, considered it to arise from the alkaline matter of the felspar being predominant, and yielding to the solvent agency of water.

Independent, however, of chemical composition, mere mechanical texture, and the general aggregation of mountain masses, has much to do with their respective durabilities. Where the arrangement of granite resembles that prevalent in the greater part of Cornwall, water gradually penetrating between the blocks and masses, freezes there, and thus slowly removes them, or transfers them to unstable ground *: while the firmer lamellar texture of much of the Scotch, Alpine, and other varieties of granite, denying

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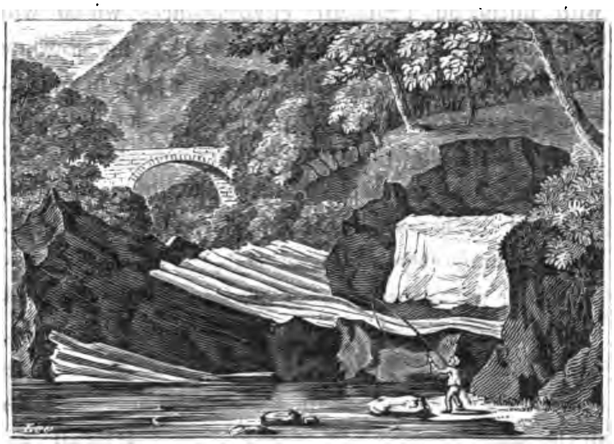
* The fissures that occur between the blocks and masses of the granites, porphyries, and similar rocks, often retain water, which in the act of freezing expands so as, notwithstanding their magnitude, with prodigious force to separate them from each other; their edges and angles become thus open to the further attacks of the weather, and by a slow dislodgement they fall into the vallies or rivers, or are at once cast into the ocean. Where the materials are of a more yielding and frangible texture this destruction is proportionally rapid: the influence of the weather upon slate mountains is often such as to produce hills of fragments at their feet; the softer substance of the secondary and horizontal strata is of course yet more easily and quickly degraded.

access of water to its fissures, is slower in suffering the decay that is referable to that very powerful cause.

Gneiss and mica-slate often form mountain masses in association with each other, and with the varieties of granite. The former is seen singularly contorted upon the coast of Lewis; and mica-slate rock is associated with the serpentine of Cornwall, and is seen in great perfection among the Scotch granitic scenery, more especially in the vicinity of Dunkeld, and in extraordinary magnificence in the lofty mountain of Benmore, the summits of which are above 4,000 feet above the level of the sea, and when seen in certain directions in respect to reflected light, dazzle the spectator by their extent and brilliancy. Ben Lawers, on the north of Loch Tay, as well as many of the neighbouring mountains, furnish the geological student with highly instructive specimens of granite passing into gneiss, and this again degenerating into mica-slate and chlorite-slate. I know of no school of geology superior to this district; the transitions, junctions, and varieties of rocks are without number, and in many places so near each other, as readily to come within the eye's grasp, and so accessible, as to furnish even the timid climber with a fine and useful series of specimens. To mention one, among the many places of this description, there is a quarry upon the high road, about three miles south of Dunkeld, in which a stratum of grauwacke is seen incumbent upon chlorite-slate, gradually passing into a fine gray roofing-slate, and this recumbent upon mica-slate. The peculiar and differing dip of the respective strata, and the singular manner in which they are pierced and traversed by veins of felspar, chlorite, and quartz, and lastly their association with micaceous iron, are circumstances which will not escape the eye of the observer in his journey through this district, the beauty and magnificence of which, in regard to general scenery, is not less than its diversified geological peculiarities.

Mica-slate abounding in garnets, and often speckled with red patches, originating in their decomposition, and becoming syenitic from the interspersion of hornblende, is prevalent upon the banks of the Tay, at and about Dunkeld; but it is in Glentilt that the geologist, both practical and theoretical, will find the most ample materials for the study of the associations and junctions of the primitive series of rocks. For a detailed account of Glentilt, I must refer those who are desirous of visiting it with the advantage of previous information to the account drawn up by the late Lord Webb Seymour, and to a very able paper upon the same district, in the Geological Transactions, by Dr. Mac Culloch. He that is tinctured with the Huttonian doctrines, will here find the Plutonists upon their strong ground, and will not feel disinclined to join in that complete contempt for the Neptunian theorists, which the language of Mr. Playfair is so well calculated to inspire. But he that is above the trammels of authority, and who dares to doubt its edicts, and to refer to his own unprejudiced and unbiassed opinion, will even here, in the Plutonic fastnesses, find matter to awaken his doubts, and to teach him the imperfection and faultiness of all geological theory.



GOW'S BRIDGE IN GLENTILT.

In the immediate neighbourhood of Blair, the Tilt exhibits upon its banks a deep section of the rocks that form its bed, and, what is remarkable, the micaceous strata here, and also at the falls of the Bruar, incline nearly at the same angle to several points of the compass, giving a curious interweavement and confusion to their assemblage. Ascending a few miles up the glen, we observe granular limestone, either embedded in, or interstratified with, the micaceous and gneiss rock, particularly well seen a little below Gilbert's bridge, and occasionally accompanied and disturbed by porphyritic dikes; and near Gow's bridge, a dike of greenstone disturbs and contorts the primary slate of the Huttonians, and contains a mass of embedded marble*. Hereabouts there is so much confusion and irregularity, such a variety of rocks, and such various inclinations of their strata, that neither descriptions nor drawings can give any thing but a remote and inadequate idea of their groupings and assemblages.

The bordering hills are frequently in part composed of granular quartz, and when this forms their summit, they are characteristically conical, as seen in Cairn-Toockie, and some others.

And lastly, dolomite, or magnesian marble, is here seen passing in a few places, and in detached spots, into a rock which bears all resemblance to serpentine.

I have enumerated these facts, which are shewn in the valley of the Tilt, because much of the fair and legitimate argument that may be founded upon them applies to the phenomena exhibited by the granitic or elvan veins of Cornwall; they will lead us to doubt the quiet crystalline deposition of the granite and its associate rocks, and may perhaps justify us in inferring, with Dr. Hutton, that they are of another source and parentage.

St. Michael's Mount, situated in Marazion Bay, on the S. coast of Cornwall, is also an interesting geological object, and shews us granite and mica-slate, not merely at their junction, but the latter rock is singularly traversed by granitic veins, which appear to break up the superincumbent slate, and to penetrate and harden it. Crystals of tin, quartz, and apatite, and small topazes, are also found in the veins of this rock.

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* See the plates annexed to Dr. Mac Culloch's paper in the Geol. Transactions.

Exclusive of Cornwall and Devon, there is little granite in England. The Malvern Hills, Mount Sorrel in Leicestershire, and a few of the ridges of Cumberland and Westmoreland, afford us specimens of this rock, but they present nothing sufficiently remarkable to be further dwelt upon at present. In the Isle of Man, and in Anglesey, granite is associated with clay-slate; and near Gwyndy, in Anglesey, the points of granite curiously protrude from beneath the slate, sometimes appearing as a felspar rock, and sometimes like granular quartz, with a few mica crystals.

The situation and characters of granitic rocks suggest some theoretical considerations, partly of an abstract, and partly of a general nature, to the most important of which I shall briefly allude, not so much on account of any intrinsic importance which they possess, as from the eagerness with which they have been animadverted upon by the contending geological schools.

The manner in which granite occasionally pervades the superincumbent stratified rocks; the damage which it often does to them at its veins and junctions; the new inclinations which it gives them; and, above all, its occasional protrusion in considerable masses connected with veins, but above the slaty and generally superposed rocks; and its occasional embedded slaty masses, are circumstances which give the Huttonian theory of its origin a plausible aspect: while, on the other hand, the delicate and well-defined line of junction with which slate and granite sometimes meet, the utter want of all fracture and violence at their contact, but more especially the slow and imperceptible transition of granite into gneiss, of gneiss into mica-slate, and of mica-slate into clay-slate, seem to favour the Wernerian view of its deposition. When, however, we fancy that we trace its crystallization from a solvent fluid, we are suddenly recalled to the difficulty of conceiving any fluid, much less of an aqueous nature, which could have dissolved and deposited granite, which is so singular and complex a crystalline aggregate; and though the notion of igneous fusion is not without its concomitant weak and objectionable points, it is so much more consistent with the phenomena, and even with experimental deduction, as to find, with all its imperfections, a more ready access to the mind of the unprejudiced observer.

As all our strata are theoretically incumbent upon granite, which we conceive to form the lowest part of the crust that envelopes the globe, and which some have been bold enough to assert as forming its nucleus, so experience teaches us that the loftiest mountains in the world are composed of the same material, and that the alpine chains of the four quarters of the globe, where the summits are not volcanic, are either of granite or its modifications and associates. Now it is not impossible, and experience renders it probable, that these exposed peaks have once been covered, like their fellows in the lowlands, with some, or perhaps with the greater number, of the rocks which we have enumerated in the order of their superposition, but that these have yielded to the ruthless fingers of time and the elements; that they have been degraded and washed away, and that the denuded and indurated materials which they once covered, now stand the more durable, but still decaying, monuments of that former order of things; the valleys, we are told, are filled with the debris of the bordering hills, and the streams and rivers wash them into the ocean, and are gradually tending to reduce the surface of the earth to an unvaried plane. Lakes are filling up; bars are forming at the mouths of rivers; mud is gradually raising itself into dry land susceptible of cultivation; and the unfathomable depths of the ocean will one day or other become soundings, and ultimately, the waters of the sea will overwhelm the land, and man's dominion will be no longer suffered upon earth; or perhaps, to take the more cheering prospect, subterranean fires may again consolidate and elevate the detritus, and new islands and continents may arise out of the ruins of their predecessors.

Although these, and similar flighty hypotheses, deserve in themselves no serious consideration, they lead us naturally to inquire as to the cause of those irregularities which the surface of the earth exhibits—the origin of hills and dales, of mountains and of valleys: but let us first temper our minds for the consideration of this subject, by recollecting the extreme insignificance of these irregularities, and the paltriness of what we are regarding as most sublime and magnificent, compared with the bulk of our planet, to which they are but as particles of dust upon the surface of an artificial globe. In speaking of the transportation of granite boulders, I have already adverted to the probable non-existence, at the period of their lodgment in their present situations, of several of the deepest and most extensive valleys of the world; and if we examine the walls, as it were, of these valleys, or at least of many of them, and observe that the same strata, in the same position, constitute the hills that bound them, we shall have little reason to doubt that they have once been continuous, and that the intervening portion has been removed. Some cases of this kind have already been pointed out, but there are others yet more decided, and upon a much larger scale, as applying not to valleys only, but to the separation of islands and continents. Look, for instance, at the two sides of the English Channel, and the same strata, with the same peculiarities, are found upon its opposite shores: shall we then disbelieve in the former continuity of these strata? Or when we discover the coast of Norway exhibiting the stratification of the Orkneys; Majorca composed of the same materials as Minorca; the geological analogy of Corsica and Sardinia; that of the opposite shores of the Gulf of Venice, and many other analogous cases, shall we be inclined to doubt the removal of the once intervening matter? Shall we not read in these correspondences, the list of which might be much extended, the former non-existence of the intervening chasms, let them be valleys, or rivers, or arms of the ocean? and shall we not have disproved the original existence of, or contemporaneous formation of the valley? and may we not reasonably conclude, that as the irregularities of valleys depend upon the relative hardness and destructibility of the materials that form their sides, from the nature of their soil, from the direction of their ravines, and from some other facts that I have already observed upon, that water has been the great agent in effecting these excavations, and that certainly the mountainous protuberances of the globe are not the invariable effect of volcanoes; that valleys have not been formed by earthquakes; and that mountains are not accumulations of sand and of mud collected by submarine whirlpools, nor great crystalline shoots, as certain German and French geologists would insist?

But if we revert to the once even and regular state of the earth's surface, and admit that impetuous torrents of water have been chiefly concerned in carving out its irregularities, where are we to look for the origin of these torrents, or how are we to account for the gigantic effects which they have left behind?

Pallas ascribes them to the effect of earthquakes and volcanoes; some have insisted upon the agency and interference of a comet, and others have attempted to accommodate their speculations to the Mosaic history of the creation, and of the deluge, without having broached any particular opinion relative to the cause of the latter phenomenon: others again have dared to bring the credibility of scripture into the field of their discussions, and have elicited nothing but the contempt and disgust of the wise and virtuous part of mankind. Surely for all these purposes, the deluge is an efficient cause; and from the evidence already adduced, as well as from that which remains to be brought forward, it will be evident that to that source we must ascribe the principal inequalities and irregularities of our present surface.

Before we quit the subject of primary rocks, I may notice a district of Britain, which for grandeur of scenery and geological interest can, I think, scarcely be surpassed. I allude to the country between the eastern extremity of Loch Ness and Fort George, and especially to the rocks over which the river Fyers pursues its turbulent and winding course. These are seen in characteristic grandeur in the neighbourhood of the small inn called the General's Hut, and the scenery becomes more and more impressive and interesting until we arrive at the celebrated falls of the river. I should call the rock a *granitic breccia*; it appears made up of numerous angular fragments of granitic materials, held together by a siliceous cement, and the aggregate is of extreme hardness and durability: masses resembling jasper and agate may also be observed in it. Dr. Garnet compares the cement, or basis of the rock, to a *lava* of a reddish hue; and a common observer would consider the whole as fragments of granite which had been united by semi-fusion, which had been softened and glued together as it were in the fire. The general aspect of the surrounding scenery is such as to impress the mind with the idea of some vast convulsion of nature having torn the rocks asunder, and shattered them into gigantic fragments: rugged crags and abrupt precipices present themselves on all sides, and the river rolls with tremendous impetuosity through deep and obstructed chasms. A rude bridge is thrown over the upper fall, whence the spectator beholds the waters of the Fyers at the distance of two hundred feet beneath him, rushing into a cavity of seventy feet in depth, whence they again emerge in perfect stillness, and running over an uneven and fragmented channel, approach the lower or grand fall. Here "the country strikes the imagination with all the gloom and grandeur of Siberian solitude," and overlooking the stream from a small rocky prominence that overhangs it, we observe the channel torn through black piles and masses of stone, which obstruct the current till it comes to a descent of great steepness and depth: here the waters, previously pent up and exasperated, suddenly discharge all their violence, and are lost in a profound abyss. The depth of the chasm in which the river flows is four hundred feet, and it bursts forth in an unbroken stream, constituting a fall of two hundred and twelve feet perpendicular height. I was so fortunate as to arrive at this spot when the falls were in full dignity, owing to previous rain; and every gleam of sun which penetrated the foliage of the surrounding firs and birch trees was refracted by the spray into rainbows, that seemed dancing in the chasm. The rugged irregularities of this district, the fragments that lie thickly strewed upon the sides of its mountains, the caverns that abound in its rocks, and the perpendicular precipice of the great cascade, considered conjointly with the peculiar texture and composition of the materials that form it, present many objects worthy the attention of the geologist; and may be regarded as recording some great natural convulsion, which has not only broken up and reunited certain primary rocks, but has again disturbed their tranquillity, and thrown them into the stupendous confusion they now exhibit.

We have now reviewed in succession the various strata which incrust the nucleus of our globe, commencing with the most superficial, and terminating with those which seem to constitute their foundation, and perhaps even the bulk of our planet. They present us with a series of records singularly interesting and eventful, and will already have appeared "as a book wherein men may read strange matters:" but their history is still imperfect, and I shall endeavour to complete the outline which I have sketched, by examining the contents of mineral dikes and metallic veins, by inquiring into the causes which tend to the disintegration and decay of rocks, and by stating the general effects of certain local agents, such as earthquakes and volcanoes.

BASALTIC COAST OF ANTRIM.

SECTION VIII.

Trap Rocks. — Basalt. — Greenstone. —Toadstone. — Amygdaloid.— Pitchstone.—Instances of these Rocks.—Staffa.—Giants' Causeway.—Isle of Sky.—Theories of these Rocks.

I HAVE attempted, in the preceding section, to give a simple statement of the manner in which the strata incrusting the solid nucleus of our planet appear to be arranged in respect to each other; and I have occasionally, where any remarkable circumstances connected with geological theories presented themselves, adverted to those theories, with a view of briefly shewing their comparative merits, but chiefly with the intention of proving the emptiness and insufficiency of most of those contending opinions which have been maintained respecting the origin of rocks, and respecting the manner in which they were deposited in their present situations. The substances which now remain for our examination are certain rocks which are very variable in their position, occurring sometimes in the company of the primary series, at others among the newest of the secondary deposites; rocks, the igneous origin of which cannot, according to the Huttonians, be questioned upon any sound principles of philosophical analogy; but which, if we believe the Wernerians, are decidedly of aqueous parentage. They constitute the whinstones, basalts, and greenstone of the one, and the trap-rocks of the other school.

The term *trap-rock* has been especially applied to those peculiar step-like or scalar declivities which mountain masses of this substance sometimes present. —In employing this term, I shall rather use it as a generic name of the rocks in question, than specifically as implying the material of which they are composed; and since the varieties known under the names of *basalt*, *greenstone*, *toadstone*, and *amygdaloid* belong to this same class, and frequently graduate into each other, I shall occasionally employ those names as characterizing individual specimens of trap-rock; designating the fine-grained, and apparently almost homogeneous rock in many instances, by the term *basalt;* the paler and greenish varieties which especially occur among the older rocks, and sometimes approximate to the nature of sienite, by the name of *greenstone;*

while the porous varieties, and those containing nodules of calcareous spar, quartz or agate, zeolites, &c. may be called *amygdaloid;* and the term *toadstone* may be confined to the speckled varieties of whin or trap-rock, which abound in Derbyshire. *Pitchstone,* too, I cannot give a better place to than among these rocks.

In regard to these rocks generally, it may be remarked that they can scarcely be said to be *stratified;* at least in this respect they are as equivocal as granite itself; like it they form irregular masses and veins, sometimes upon and sometimes under other rocks, sometimes interposed between them, and in almost all their varieties an analogy may be traced out to the lavas produced by the superficial volcanoes of the earth. Indeed, the resemblance is sometimes so great, that many geologists have mistaken whinstone for lava, and many rocks, regarded as the remains of extinguished volcanoes, have proved to be true basaltic formations.

Hornblende and felspar are distinctly visible in some of the unequivocal varieties of trap-rock—the former very abundant, and the proportion of black oxide of iron being such as to give to the substance a decided magnetic character. In other cases distinct crystalline texture is lost, and the mass appears nearly or quite uniform and homogeneous.

This rock, under the name of greenstone, is seen in characteristic masses associated with the granite, mica-slate, and serpentine of the Lizard in Cornwall. It is seen accompanying clay-slate and old red sandstone near Kington and Radnor in Wales; and upon the northern sides of Snowdon, Plymlimmon, and Cader Idris, coarse-grained and with regular crystals of hornblende in one place, and in another, fine-grained, homogeneous, and even basaltic or columnar.

In Derbyshire, under the name of toadstone, I have already noticed the singular disposition of this rock, associated with mountain limestone; and with new red sandstone, or red marle in the coal-fields of the north near Edinburgh, in Shropshire, and elsewhere; and in Antrim we find it variously blended with the sandstones and chalk, and even sometimes lying upon them, so as to constitute beds superior to those of the newest secondary formations.

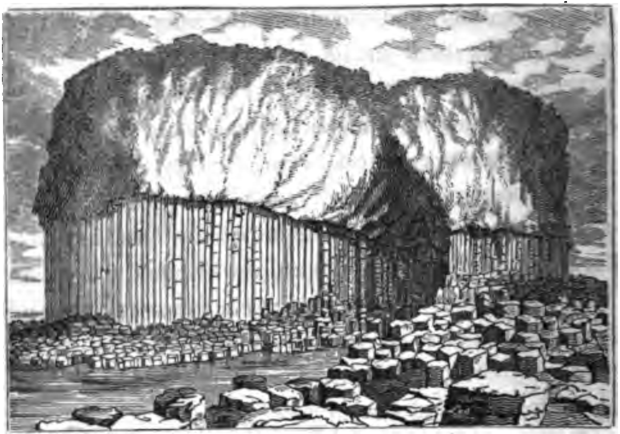
These instances, which might be greatly multiplied, will suffice to illustrate the varied position of this rock. In regard to its aspect, we observe it in Cornwall forming blocks and masses not unlike the granite of that country; sometimes, as in the coal-strata, it forms immense walls or *whin-dykes;* in Derbyshire, it may be said to be stratified; in the Isle of Mull, and elsewhere, it is massive and amorphous; and in many places it is columnar, of which the coast of Antrim, the Island of Staffa, and some parts of Mull, furnish such magnificent instances. The Isle of Mull, Ulva and the Treshamish Isles, exhibit trap-rocks and veins in such variety, and more especially the Isle of Mull, which is also highly interesting as a school of granitic geology, that I am sorry to pass it over with a bare mention. The trap-veins of the Isle of Sky are not only remarkable for their singular extent and arrangement, but for the changes which they produce upon the rocks they penetrate, and which are of such a nature as to throw some few rays of light at least upon the most recondite chemical phenomena connected with geology. I do not mean to say that these peculiarities belong exclusively to Sky, for they are more or less distinctly observed among all similar associations of rocks, but in that island they are eminently distinct.

Among these veins there are two which penetrate the white marble of Strath, (Mac Culloch's Western Islands, i. 399,) and which have been exposed by the operation of quarrying. Now the mere fact of the vein passing through marble is not common ; but what is truly curious is, that at their junction the trap passes into a substance resembling serpentine, and penetrated by fissures containing steatite ; while the marble acquires all sorts of colours, and changes in composition from argillaceous to magnesian, and from magnesian to siliceous. Among the veins of Strathern, a similar connexion between the veins of basalt and steatite, and serpentine and marble, also occurs ; but there the veins, instead of penetrating marble, are in calcareous sand. Also in Glentilt, and in various others parts of Sky, trap-veins intersect and cut off coal formations, and sometimes the same vein of trap exhibits the rock in its several varieties of basalt, greenstone, and amygdaloid. I do not endeavour to state the names of the particular places or spots at which these appearances occur, for they defy all ordinary powers of orthography, but many of them are accurately laid down and described by Dr. Mac Culloch, in his laborious geological work upon the Western Isles of Scotland;—his descriptions are so minute, and his observations so perfectly untinctured by geological prejudice, as to leave the student nothing further to wish for in that line of description.

Of Staffa, Dr. Mac Culloch has given us a minute and accurate account, enriched by a variety of remarks, of infinite use to the traveller.

The island is about a mile and a half in circumference, and its greatest elevation, which is upon the south-west side, is about 144 feet. Its lowermost bed upon that side is a basaltic conglomerate. The columns are compact and uniform in texture, of a dark grayish-black colour interiorly, and of a rusty-brown where exposed to the weather. Amorphous and columnar basalt, and a stratum of pebbles foreign to the island, which were referred to in the first section, form its upper bed, or stratum.

The most celebrated object in this island, and justly so, too, is Fingal's Cave, though there are two others of considerable grandeur and interest. The entrance to this cave resembles, in shape, a Gothic arch, about



STAFFA, WITH THE ENTRANCE OF FINGAL'S CAVE.

70 feet in height; the pillars which bound it vary from 18 to 36 feet in height; its breadth is between 40 and 50 feet, which is also the average height of the interior; its length is 227 feet, and preserves a considerable degree of regularity throughout, its sides being columnar, and, in many places, broken and irregularly grouped, so as to catch a variety of direct and reflected tints, mixed with unexpected shadows, and producing a picturesque effect, which no regularity could possibly have given. The sea never entirely ebbs out of this cave, but the broken range of columns which forms the exterior causeway is continued on each side within it, forming upon the east a footpath, which is so irregular, slippery, and broken, as not to be traversed by any but those possessed of a very steady foot and head. This cave has been frequently

described, but no description is adequate to the representation of its varied beauties and singular associations. Dr. Mac Culloch, who has frequently visited it, and each time with new admiration, has justly observed, that were it even destitute of that order and symmetry, that richness arising from multiplicity of parts, combined with greatness of dimensions and simplicity of style, which it possesses, still the prolonged length, the twilight gloom half concealing the playful and varying effect of reflected light, the echo of the measured surge, as it rises and falls, the pellucid green of the water, and the profound and fairy solitude of the whole scene, could not fail strongly to impress a mind gifted with any sense of beauty in art or nature.

The uppermost basaltic bed of this island consists of a confused mass of small columns and is of variable thickness, its naked surface having a singularly tessellated appearance. This bed forms, in the language of architecture, the entablature required to give their due office to the columns which form the middle range.

Another cavern in this island deserves notice, as a contrast, by its irregularity, to the regular columnar arrangements of Fingal's Cave; it is usually called Mackinnon's Cave, and is more easy of access than the former. It presents a large entrance, near 50 feet square, and extends about 250 feet into the rock of conglomerate; while the superior part of the front consists of a range of columns, hollowed into a concave recess above the opening, and overhanging the concavity like a geometric ceiling.

A third cave, rarely visited, but curious from the singular grouping and regularity of its columns, is called the Boat Cave; its dimensions, however, are greatly inferior to those of either of the former.

The Giant's Causeway, and the various promontories or head-lands of the coast of Antrim, form another basaltic district of matchless grandeur and interest; yet, to prevent the disappointment which I experienced in visiting these wonders of nature, after having seen the still superior and more insulated magnificence of Staffa, I would advise the traveller who has the choice, to proceed first to the north of Ireland, and thence to Staffa: for although Bengore, Pleskein, and Fairhead are in themselves superior to any part of Staffa, they do not rise in the same abrupt manner from the ocean; and being everywhere accompanied and surrounded by lofty cliffs, are not calculated to excite those mingled emotions of surprise and admiration, which so overpoweringly assail him who lands, for the first time, on the columnar and cavernous shore of Staffa.

The Causeway itself consists of three piers of columns, which extend some hundred feet into the sea, and are walled round, as it were, by precipitous rocks, from 2 to 400 feet high, in which are several striking columnar assemblages, vertical, inclined, curved, and horizontal, and in some places looking as if wedged or driven into the surface of the precipice, the ends of the columns only remaining in sight. Bengore, which bounds the Causeway on the east, consists of alternate ranges of tabular and massive with columnar basalt; but amidst the various and grand objects of this coast, Pleskein is perhaps the most striking: it presents several colonnades of great height and regularity, separated from each other by tabular basalt; and at Fairhead there is a range of columns of from 10 to 20 feet diameter, and between 200 and 300 feet high, supported by a steep declivity, which forms a stupendous terrace nearly 600 feet above the waves beneath.

Sometimes basalt rises in massive and abrupt rocks, assuming the appearance of an uniform and homogeneous substance, and scarcely exhibiting any of that singular tendency to columnar regularity, which we have just had occasion to admire in Staffa; the Castles of Dumbarton, Edinburgh, and Stirling, are built upon such masses. At other times it forms low, rugged, and unpicturesque strata, sometimes very remarkably bent, but without forming decided columns.

Basalt is not unfrequently found in veins, traversing masses of the same substance, and of other rocks; and the phenomena which these veins produce in their passage depend, of course, upon the nature of the materials traversed; they are, however, in most instances, such as to leave, independent of any other consideration, very probable marks of their igneous origin. Thus the veins, or dykes, are generally most crystalline in the centre, and acquire a more even and fine-grained fracture upon their sides; they harden and consolidate the lapideous substances through which they pass, producing effects analogous to those which may be conceived to result from the operation of matter in igneous fusion, injected among the strata, and which Sir James Hall succeeded in imitating artificially, by submitting the substance to the action of intense heat, under a pressure suitable to restrain the escape of gaseous matters. The sandstone near Edinburgh is thus hardened by the action of the whin-dykes, and there, in their immediate contact, it becomes of a jaspideous appearance and fracture; and in some places pieces are broken, and have been apparently floating in the matter of the dyke, and are proportionally hardened and modified. These appearances correspond in some respects to the changes effected in the slate of Cornwall and elsewhere, by the veins of granite, and of porphyry, or elvan; but some of the difficulties, in regard to their source, which I hinted at in the last section, do not apply to veins of greenstone and whin-dykes, which are certainly of less equivocal origin.

The limestone of Antrim alternates with basalt, and is in many places invaded by its dykes or veins, and in some overtopped by basaltic strata, connected by small and narrow ramifications, with inferior or underlying masses of the same rock. Here we have the limestone changed to marble, and the flints putting on that opaque and red appearance which they are well known to acquire when subjected to artificial heat; but the fact which of all others favours the igneous original of basalt is derived from an examination of the changes which it effects in traversing coal-strata. The dislocations and fractures of the coal-field have been already described as one consequence of whin-dykes—another is the formation of chasms, in which carburetted hydrogen is pent up under great pressure, and which, when any accidental opening is made into them, continue to emit torrents of that gas, forming what the miners term *blowers;* and what is also equally to the purpose, the coal is found charred or turned into coke in the vicinity or contact of these dykes.

Now, if we consider these facts, and if we associate them with others of a similar tendency; if we connect the theory with the experiments of Sir James Hall, and above all with those of Mr. Watt upon the fusion and cooling of certain earthy compounds, we shall not, I think, refuse to assign a high degree of plausibility to that theory which compares basalt to lava, and considers it of igneous origin; and consequently also to *those parts* of the Huttonian doctrines which are mainly founded upon the phenomena and effects of whin-dykes.

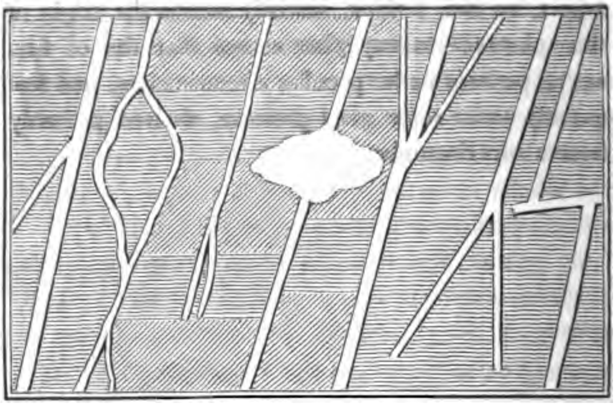
Basaltic rocks vary extremely in their tendency to decomposition. In some places they are seen in rapid decay, crumbling down into a brown or red soil of a tenacious clayey character. In others they are of great and even remarkable permanence, and the columnar varieties are so little acted upon, that in the Causeway and Staffa, and upon many parts of Mull, the pillars retain the acuteness of their angles, although subjected to the incessant operation of the waves, and to those alternate exposures caused by the tides, which so few rocks are able to resist. Where massive basalt or trap rocks are pervaded by veins of the same material, the vein is usually more indurated and durable than the mass which it penetrates; and not unfrequently the course and dimensions of the vein may be traced in relief upon the comparatively worn and degraded surface of the rock which it passes through.

In the Isle of Sky there is a large district of decomposing trap-rocks, which may well be selected in illustration of the decomposition of basalt. The north-east portion of the island exhibits a long ridge, commencing at Portree, and stretching away to the point of Aird, which, rising by a gradual acclivity from the west, terminates to the east by a rapid descent, often displaying extensive precipitous faces, and acquiring an altitude of upwards of 2000 feet. At the highest point, called the Storr, the summit of the mountain is cut down in a vertical face 4 or 500 feet high; while the steep declivity below is covered with huge masses of detached rock, which are the more indurated and durable remains of the cliffs above. These are combined in various and intricate groups, while their massy bulk and squared and pinnacled outlines present vague forms of castles and towns, resembling, when dimly seen through the driving clouds, the combinations of an ideal and supernatural architecture. The most remarkable of these insulated masses is 160 feet high, assuming at a distance the aspect of a spire, and presenting from afar a sea-mark well known to mariners.

Having taken frequent opportunities of adverting to the proofs illustrating the igneous origin of basalt, it might possibly be expected that I should have equally described the phenomena belonging to this formation, which are supposed to demonstrate its aqueous production. Upon this subject, however, I should presume that a very few and brief observations will suffice. As far as basaltic dykes are concerned, it has been imagined that fissures existing in the rocks they traverse have been filled by an aqueous solution of the materials found in the dyke, and these, from some cause, by no means apparent, to have consolidated. Then, as to all those appearances of induration and fusion which I have elsewhere referred to the heat of the matter of the dyke,—they are supposed to have originated in the solution having percolated and congealed in the walls of the vein. But if we must theorize, the nature and extent of the hardening, and the various characters, both of the vein or dyke itself, as well as of the pervaded rocks, are surely more consistent with igneous eruption than with aqueous infiltration; to say nothing of a host of other objections which present themselves, and which I shall more particularly insist upon when adverting to the Wernerian hypothesis of the filling of metallic veins. Indeed in coal-mines we have too decided evidence of the igneous origin to substitute any other hypothesis.

In respect to columnar basalt, the Neptunians are yet more inconsistent with the facts which its minute examination affords.—They here refer us to that columnar appearance which certain substances assume on passing from a pasty to a solid state during their desiccation. Something of this kind may be seen in starch, and occasionally in mud, which in the process of drying has split into irregular angular masses. But to say nothing of the state of the iron in basalt, or of its insolubility, there should in such a case have occurred fissures and cavities between the columns, announcing the shrinking of its mass during its induration, a circumstance which is never observed.

When, therefore, we consider the various phenomena connected with basaltic dykes, and more especially with columns of basalt; and when we reflect upon the analogy in composition, as well as in appearances, that holds between basalt and some kinds of lava; and, lastly, when we observe lava itself, under certain circumstances, assuming a columnar and truly basaltic aspect, we can, I think, scarcely ascribe the origin of this substance to any other source than that of fire, acting perhaps under peculiar circumstances, and frequently under some great pressure, derived probably from a superincumbent ocean.



SECTIONS OF METALLIC VEINS.

SECTION IX.

Metallic Veins. — Theories of their Origin. — Their peculiarities. — Cross Courses, and other Irregularities. — Modes of Working and Discovering Veins.

I HAVE had frequent occasion to advert to the existence of fissures, that disturb the continuity of the strata of the earth's surface, and that are filled with materials differing from those of the rocks they traverse. I now propose, more exclusively, to notice these subjects, examining the geology of *metallic veins*, or, as in this country they are often technically termed, *lodes* or *courses*.

In respect to the origin of these important deposites of our mineral and metallic treasures, it deserves, in the first place, to be remarked, that they almost always bear evidence of having been formed and filled subsequent to the production of the rocks in which they occur; and that it is only in a very few instances that the utmost stretch of theory will permit us to consider a vein as a mere accidental irregularity, coeval with its including strata, or contemporaneous with the rocks which it traverses.

To give an idea, therefore, of the nature of a vein, it has been common to compare it to a large crack, or irregular fissure, having something of the appearance, in many instances, of those which form in clay or mud, during its gradual sinking and desiccation; and then to conceive it subsequently filled with those various substances which occur in it, and which are consequently of a nature totally dissimilar to the materials that form the sides or walls of the veins.

Such, indeed, is a sufficiently correct representation of the circumstances that attend many metallic veins. There is a mere fissure in the rock, not interfering with the parallelism of its strata, and formed, as it were, by some gradual and quiet operation. But, in other cases, the appearance of a vein is wholly different, and announces the result of some much more violent and sudden operations. The parallelism of the strata is disturbed, and that greatly; the walls, instead of being similar, are evidently displaced, and the adjacent substances irregularly heaved, or thrown into new postures, by some great convulsion which caused the fissure in question. This may have been derived from volcanic explosions, or earthquakes, or from some other cause, by which the strata may have been ruptured, leaving, in some instances, empty fissures, subsequently receiving their contents, and at others filling the veins with lapideous or metallic bodies.

The notion of cracks and fissures existing in the strata, and afterwards filled with the various substances constituting the vein, and flowing into it from above, may serve to give an idea of the Wernerian theory, applicable to this intricate part of geology; and it ascribes the occasional irregularities or dislocations of the strata to the falling in, or slipping down, of one portion of the rock, soon after or during the shrinking that occasioned the aperture. It is then supposed that various solutions flowed into these empty chasms, and that, crystallizing quietly and slowly, they lined them successively with the various bodies which now form the contents of the vein.

I need scarcely say that this theory at its very outset puts all the principles of chemical philosophy at defiance: attributing as it does an universal solvent power to some imaginary liquid, more powerful even than the alkahest of the alchemists; withdrawing that fluid at pleasure; and enabling it successively to perform the most discordant and opposite functions. Nor are we informed how it came to limit its depositions to the veins themselves; not even without overspreading the circumjacent strata, but without leaving any trace behind upon ground where it is supposed to have rested, infinitely more favourable to crystallization or deposition than the tortuous chasm to which its powers seem to have been nearly limited, or, indeed, entirely confined. The Neptunist has urged, in favour of his theory, the occurrence of fossils, of fragments, and of pebbles, in veins, evidently derived from the superficial strata, and demonstrating them at some period to have been open from above; and such things do, although rarely, occur. Werner alludes to a vein filled with rolled pieces at Joachimsthal; to another in Dauphiny; and Mr. Gilbert found rounded pebbles cemented together by tin-stone in a vein of the Relistian Mine in Cornwall: all which proves that some pebbles may have occasionally fallen into veins, and that at a very remote date, without in any way demonstrating that the crystalline aggregates of veins are all of similar origin.

If we now advert to the Huttonian theory, we shall there see the appearance and phenomena of veins attributed to the injection of their contents from below in igneous fusion,—an hypothesis of which the most one can say is, that it involves fewer absurdities, though not, perhaps, fewer difficulties, than the former —for there are facts to be observed in the direction of veins, in their action upon the neighbouring strata, in the arrangement or order of their contents, which entirely militate against the notion of this method of their production, and which leave us at an utter loss for any plausible explanation consistent with the known physical and chemical attributes of matter.

That all rocks are occasionally penetrated by veins, but that those which are metalliferous are limited to the older series, has been stated in our general enumeration of the contents of different strata. It has also been remarked that regular metalliferous veins most frequently take the direction of east and west, or nearly so, and that those which cross them, or run nearly in the direction of north and south, are generally filled with other substances. I say generally, because there are several exceptions to the statement I have made, just as there are east and west veins destitute of the metals.

It is often imagined that veins are widest above, and that they gradually taper off and are lost at great depths in imperceptible filaments; but this is by no means the case; and hitherto I believe the actual termination of a vein, properly so called, has never been seen. Cross courses sometimes suddenly interrupt a vein, and its continuation cannot again be discovered; sometimes veins dwindle into thin filaments, or become so impoverished by diminution in their metallic contents, as not to justify the expense of the pursuit; but in other cases the continuation of the vein intercepted has been discovered, and the thin filaments or threads have in several instances been known to reunite, not merely into a profitable vein, but even into a large bunch of metal.

Veins generally pursue a straight line, or nearly so; and if they deviate from it, they reassume shortly their former regularity, their direction being downward, not perfectly perpendicular, but more or less inclined to the north or south. This inclination is called the *underlie of the lode*, and is very variable. Mr. Phillips, in his excellent practical account of the Cornish Mines, printed in the *Geological Transactions*, and again in his *Geology*, tells us that in Cornwall some of the veins only underlie a few inches from the perpendicular in a fathom, but that in others the underlie is a fathom, or even more in the same extent. When a vein pursues a steady and regular progress, the term *rake* is generally applied to it; but where it bulges out into irregular masses, and forms, as is sometimes the case, large horizontal beds of metal, the term *pipe vein* is often applied to it, or the bulge is called a *floor* of metal. Here also we may mention the different direction which different veins often take. In the mines of North Wales, in most of those of Cumberland and Derbyshire, in the great mines in Arkendale and Swaldale, in Yorkshire, the veins of lead, like those of copper in Cornwall, are east and west; but, on the other hand, the lead and silver of Cornwall is in many instances chiefly found in north and south veins:

and the smaller veins of Cumberland, and the counties adjacent, traverse the strata in almost all directions. These are the exceptions to which I adverted, in alluding to the general east and west direction of veins.

In regard to *width*, metalliferous veins are extremely various, and their value is not always proportionate to their diameter. Some of the veins of Cornwall are from 30 to 40 feet wide, but less productive than when only 3 or 4 feet in width; and in some cases they shall be worth working, from their extreme richness, when not more than 2 to 4 inches wide; and in relation to this subject, the nature of the pervaded country must be taken into the account. In Cornwall, if, on working in the course of a vein, the country is found to assume a greater hardness in a considerable degree, the vein generally becomes narrow.

In Derbyshire, and in the North, the lead-veins in the limestone are remarkably affected by the shale, sandstone, and toadstone, and in some places entirely cut off; while in others they divide into very small ramifications, which in the limestone again unite into a large continuous vein.

In Mexico, they are upon a larger and more magnificent scale, proportionate, as it would seem, to the greater extent and elevation of the mountains of the New World. Humboldt adverts to veins containing silver ore from 60 to 90 feet wide.

In many of the richest metallic veins, the ore is separated from the walls of the rock by a coating of clay, probably the decomposed rock, which varies in thickness, but which sometimes is wanting upon one side. In other cases various sparry substances intervene, and in others the metallic ore itself forms a close junction with the rock. But in these, as well as in other respects, the texture of a vein is so capricious, that any general description must be taken with many limitations and exceptions. This is more especially the case in respect to the contents of veins at different depths, which are liable to such diversities as to baffle all conjectures founded even upon extensive and careful experience.

In Cornwall, symptoms of metal rarely occur at a less depth than 30 fathoms, the upper part of the lode being full of clay, gravel, and the debris of the neighbouring country. If at that depth there occur a quantity of friable ferruginous clay of a yellow or red-brown colour, and provincially called *Gossan*, the proximity of tin or copper may be anticipated. But blende, iron pyrites, chlorite, quartz, and clay, may prevail for many fathoms without any more valuable products. Tin and copper are often found in the same vein, but the tin almost always precedes the copper; and in Cornwall many of the richest copper-mines are the continuations of tin-veins which had been imagined to be exhausted, or which had been given up, from their depth, before the great improvements in draining mines by steam-engines had arrived at their present excellence. Even in rich and productive veins, the valuable portion is seldom in such abundance as to leave by its removal a perfectly empty chasm; though this is sometimes the case, as in the Paris Mine in Anglesea, where an immense space or quarry indicates the extent of the removed treasures: generally there is left a quantity of quartz, calcareous spar, fluor, iron pyrites, or clays, usually termed *Deads*, and which often are in so far useful, that they serve to support the walls of the vein, and are a durable substitute for the timber, with which, in very rich veins, they are obliged to support the impending rocks, and which often from its falling in gives rise to disastrous accidents. An instance of this kind is mentioned by Mr. Phillips, as having occurred in Cornwall, in the copper-mine called Wheal Alfred, one of the veins of which was hollowed out for about 100 fathoms deep, so as to form a very extensive chasm; and, notwithstanding great labour, skill, and expense had been bestowed, and the most substantial timber employed to keep apart the walls of the vein, many thousand tons came down in an instant.

Among the irregularities of veins* there is one, not of frequent, but occasional occurrence, and which throws great difficulty upon many of the theories of veins; the miner shall suddenly arrive at a piece of dead ground in the midst of the vein, leaving only a small connecting string of ore on each side, and sometimes extending many fathoms in length and depth. In these cases, the miner says that the vein or lode has *taken horse.*

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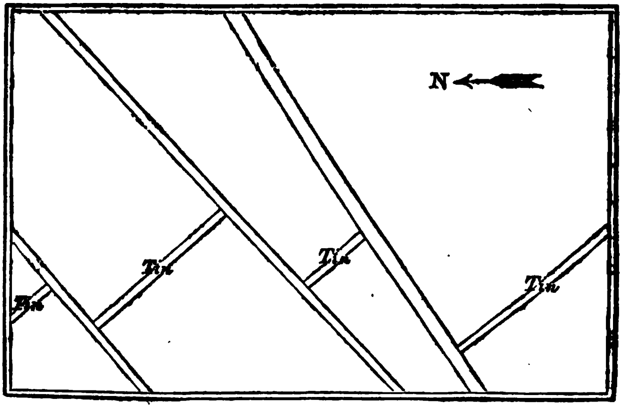
* The copper and tin-veins of Cornwall are generally much more irregular than the lead-mines of the north of England, and hence more difficult to work.

The disturbance of veins, by cross courses, furnishes not the least important part of their geological history; and as one metallic vein is sometimes intersected by another, apparently showing them to be of different dates, so we find that cross-veins are usually of more recent date than those containing metallic ores, as is demonstrated by the manner in which they are cut through and traversed; and both seem to be, as I have already stated, of a posterior date to that of the traversed rock, as is shewn by the division in the parallelism of its beds. When I have said that metalliferous veins, in all parts of Europe, and even in the great mining district of America, affect an east and west direction, and that the north and south veins are not metalliferous, and of a later date than the others, I must again beg to observe that this statement is merely meant to apply *generally*, and that in England and elsewhere it is open to frequent exceptions, as in regard to the veins containing lead and antimony in Cornwall, and also, even in some instances, tin, has been found in such a cross-vein.

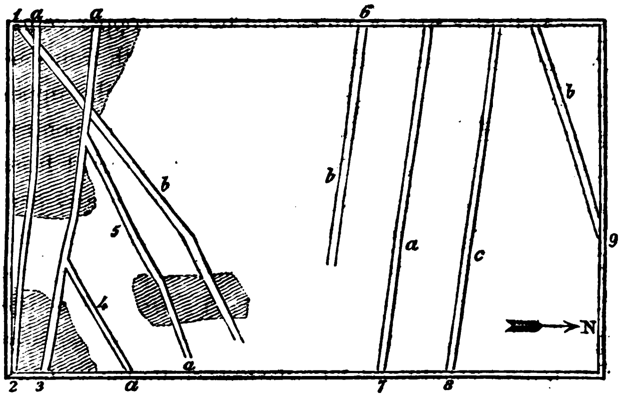
In a few cases the cross course is rather advantageous than otherwise to the interests of the mine: a poor vein often becomes very productive near the cross course, and sometimes, when of indurated materials, it prevents the water of the neighbouring country from troubling a mine: but the various interruptions which are thus occasioned in the metalliferous vein are more commonly a source of great vexation and trouble to the miner; and though these disturbances are now much better understood than formerly, cases of great intricacy and difficulty frequently occur, which baffle the most skilful efforts of the scientific and experienced miner, and lead to incalculable expenses. Another way in which it is possible that a cross course may be of service is, by heaving the metallic vein, so as to bring it nearer the surface. This is well illustrated in the following section of Pink Mine taken from "Pryce's Mineralogia Cornubiensis," where a tin-vein is intersected in its course by three gossans, and heaved each time, at first twenty-two fathoms, then nine fathoms, and then about two.



SECTION OF THE PINK MINE.

In the mines of Derbyshire, and in the lead-mines of the north, I have adverted to the modified size and contents of the metallic vein depending upon the nature of the strata through which it passes, and especially to the influence of the grit and toadstone, in impoverishing or intersecting a vein large and productive in the limestone. In Cornwall, both the granite and slate are traversed by veins of tin and copper; and here a very curious question, both in its practical and theoretical relations, presents itself, namely, what changes does the vein suffer at the junction of the slate and granite? The mines of Cornwall enable us to answer this question, and it generally happens that the derangement suffered by the vein is very trifling, even where slate and granite alternate, as is often the case, in consequence of the veins of the latter penetrating the former rock; and in Huel Gorland, a vein passed between granite and slate, having one of its walls of one substance and the other of the other. Tin Croft Mine, the annexed section of which is copied from Mr. Phillips's paper, also offers some remarkable alternations of schist and granite, as well as some peculiarities in respect to the number, underlie, dimensions, and contents of its veins. There are here five copper veins, three of tin, and one mixed, in about a furlong of country, north and south. Of these, two only proceed in a straight line; one alters its direction repeatedly in a gradual approach to the perpendicular, and is intersected by two copper veins; one of these, the south vein, varies in width from one to six feet, and was rich in copper through the upper granite and slate, but became hard and poor upon re-entering the lower granite. Another vein varied from one to twelve feet in width, and running nearly perpendicular, sent off two other veins or offsets, becoming very poor at the point of their separation, but containing shoots of ore between them. Below the latter it became richer, and was worked to a depth of one hundred and twenty-five fathoms from the surface: the first offset was a poor vein, but the second very abundant in copper pyrites; the sixth vein yielded a little tin; the seventh yielded copper and iron pyrites; the eighth yielded tin and copper, sometimes mixed, and sometimes running side by side down the vein; and the ninth was extremely prolific in tin for a depth of forty-five fathoms from the surface, when it became as poor, and filled with iron pyrites; but at a greater depth, where it traverses another mine, it has been found as rich in copper as it was near the surface in tin.

In vein No. 3, granite was found on one side, and slate on the other, and detached masses of granite and slate were found both in it and No. 2; and frequently where the vein traversed granite, it contained fragments of slate; and where it passed through slate, there were found in it detached masses of granite.



a. Copper Veins.
b. Tin Veins.
c. Copper and Tin.

The shaded parts are Granite, the rest Slate.

The account of this mine will serve to give some idea of the intricacy, irregularity, and uncertainty in the disposition, number, and contents of veins; it also alone furnishes such a singular assemblage of contradictions to all received theories of veins, as to shew their utter inadequacy, and the uselessness of bestowing further time upon the contradictory statements and empty pretensions of their inventors *.

In the texture and hardness of the principal rocks traversed by these veins, namely, granite and slate, there is the greatest possible variety, but I am not aware that any concomitant effects upon the metallic vein have been proved. The harder the rock, of

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* Another remarkable instance of irregular disposition of veins is described and figured by Mr. Williams, in his account of Huel Peevor, in the "Geological Transactions," iv. 139.

course the less profitable the vein, or rather the more expensive the operations of the miner. In slate alone Mr. Phillips mentions the expense of sinking a shaft to vary from 5*l.* to 55*l.* per fathom; and occasionally a bed or channel of some extremely hard substance almost arrests the entire progress of the work; but this occurrence is not frequent*.

The means of arriving at a vein, or working a mine, are varied according to the nature of rock or country which it traverses, and are dependent upon an infinite variety of adventitious circumstances frequently connected with those under which the vein was originally discovered, and which discovery is sometimes the result of accident, such as by making roads, cutting ditches, or draining land; or sometimes it is arrived at by the discovery of fragments or pebbles of ore in the beds of rivers, or in alluvial soil, through which streams formerly appear to have passed. Thus the ancient mode of shoding for tin consisted in tracing certain stones containing tin, to the vein whence they had been detached. Sometimes the course of a vein may be learned by the nature of the fragments and stones upon the surface, more especially by their ochreous tints. A knowledge, too, of the substances which, in different countries, usually accompany the ore of metal forming its *gangue* or *matrix*, is often of much importance in these inquiries. In Cornwall, quartz is most abundant; in Derbyshire, carbonate of lime and fluor; in Yorkshire, cawk, or sulphate of baryta; and in Cumberland, cawk and fluor.

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* "The economy of a mine may be considered under the following heads:—

1. The nature of the agreements between the owner of the soil and the mine adventurers.

2. The arrangements between the partners or adventurers themselves, and the system of control and management appointed by them.

3. The mode of employing and paying the miners and workmen in use among the agents of the principal concerns.

4. The purchase of materials for carrying on the undertaking.

5. The sale of the ores from the mine adventurers to the smelting companies."

On the Economy of the Mines of Cornwall and Devon. By John Taylor, Esq. Geol. Trans. ii. 309.

Sometimes the springs in the vicinity of metallic veins are so tainted as to lead to their discovery. Of this a singular instance occurred some years ago at Dolgelly, where the peat in the neighbourhood of the vein was so impregnated by sulphate of copper, as to leave copper in its ashes when burned. When this was ascertained, the injured vegetation guided to the vein. By the retention, therefore, of these contaminated waters in the soil near the vein, it may become unfit for vegetation, and thus the sterility of certain patches of land may indicate the existence of metallic bodies in the district.

There are no class of persons more curiously superstitious than miners, and hence a variety of omens, connected with the interference of agents from the spiritual world, are among the items of their creed. Sometimes while underground they fancy they hear another pick at work, announcing the presence of a little man, or pixey-knocker, in some neighbouring cavern, and the consequent vicinity of a good course of ore. Sometimes even the divining rod is resorted to; and sometimes it is said that flames of light, dancing about a mining district, have suddenly perched upon the vein, and there rested for a time and disappeared; a circumstance, this, not improbably connected with electricity, and referable perhaps to the good conducting power of the vein, either from the ore or water which it contains: indeed, almost all rich veins abound in water, which gushes from various parts, often of very different temperatures; the warmer it is, the more favourable to the production of ore. Hence, upon deep and rich mines, several steam-engines of large dimensions are requisite to carry away these subterranean torrents.

The habits, however, of the miner are those of industry and perseverance, which sometimes tempt him to exploits that excite astonishment at his venturous hardihood. "The very idea of a descent beneath the surface of the earth has something in it of the terrible, at which those shudder who are unacquainted with practical mining; but such is the force of habit, that any other employment rarely tempts him to forsake his own. The occasional perils of his occupation are scarcely noticed, or if noticed, are soon forgotten. He walks, often in the middle of the night, and in all weathers, two, three, or more miles to the mine, undresses, and puts on his underground clothes, and with his tools slung over his shoulder, descends by ladders, a depth of a thousand or twelve hundred feet, assisted by the light of a small candle, and works in the bottom of the mine six or eight hours, amidst the noise of the working of the pumps in drawing the water, with as much alacrity and with as little sense of danger as he would feel amidst his ordinary occupations above ground. We should be inclined to feel pity for the wretch who, as an atonement for his crimes, should be compelled to undergo what the Cornish miner voluntarily undertakes for a small pittance, and that even of an uncertain amount *."

"The mine of Huel Cock, in the Parish of St. Just, is wrought eighty fathoms in length under the sea, below low-water mark, and the sea in some places is but three fathoms over the back of the workings, insomuch, that the tinners underneath hear the break, flux, ebb, and reflux, of every wave, which, upon the beach overhead, may be said to have had the run of the Atlantic Ocean, for many hundred leagues, and consequently are amazingly powerful and boisterous. They also hear the rumbling noise of every nodule and fragment of rock, which are continually rolling upon the submarine stratum; which altogether make a kind of thundering roar, that would surprise, and possibly engage the attention of the curious stranger. Add to this, that several parts of the land, which were richer than others, have been very indiscreetly hulked and

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* W. Phillips, Geol. Trans. ii. 144.

worked within four feet of the sea, whereby, in violent stormy weather, the noise overhead has been so tremendous, that the workmen have many times deserted their labour, under the greatest fear lest the sea might break in upon them *."

In former times, when a vein of metal was discovered, it was worked to a certain depth, and then often abandoned, in consequence of the insufficiency of the pumps to carry off the water, or of the expense incurred in their erection and working. In certain situations, however, it was found that this water ran off at lower levels, and that in most instances it might be carried away by an underground tunnel, commencing at the foot of the hill, penetrating to the vein, and thus forming a communication with the working of the mine and a neighbouring valley. These tunnels are now called *adits*, and when it is resolved to try a vein, one of these underground passages, about six feet high, and two and a half wide, is begun at the bottom of the neighbouring valley, and driven up to the vein for the purpose of carrying off the water; or if a mine has an engine upon it to raise the water from a greater depth than that of the entrance of the adit, the engine then, instead of having to lift the water to the surface, throws it off with diminished labour at the adit. In general, adits are nearly horizontal, for although a declivity would accelerate the drainage, it would, in a passage of any length, be attended by the disadvantage of entering the mine at less depth. The importance of draining mines by adits has led to some gigantic undertakings of this kind. The great Cornish adit commences in a valley above Carnon, near the sea, and branches off in its course in several directions to about fifty mines in the parish of Gwennap. Most of these are much below its level, and the water is raised into it by numerous steam-engines. The entire length of this adit, with its various branches, is about twenty-six thousand fathoms, or nearly thirty miles; but the greatest length of any one branch from the mouth is at Cardrew Mine, and is four thousand eight hundred fathoms, equal to five miles and a half; its greatest depth is at Wheel Hope, equal to seventy fathoms. It empties itself into Falmouth Harbour.

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* Pryce, Mineralogia Cornubiensis.

The adit of the Duke of Bridgewater's collieries at Worsley is about thirty miles long, and navigable. Another great work of this kind is the tunnel of the Tavistock Canal, through Morwel Down, joining the River Tavy with the Tamer, and nearly two miles long underground, at a depth in many places of one hundred and thirty yards from the surface. The section of this hill shows the beds or dykes of quartz and porphyritic rock which traverse the killas or slate, of which the bulk of the hill is formed, and the direction of which is nearly parallel, ranging east and west. It also shows the differing inclination or dip of the metallic veins.

Another great adit is the Nantforce level, near

Alston Moor, driving at the expense of the commissioners of the Greenwich Hospital ~~estates; it will~~ drain many valuable mines.

Where an adit is of any length, it is obvious that the air would become stagnant in it, and hence the necessity of fresh supplies, derived from perpendicular openings, which are called *shafts*, and which also serve for the removal of the produce, and the more direct access of the miners to their work. From these shafts, *levels* or *galleries* are excavated, and driven in various directions, either for exploring or removing the contents of the vein.

The states in which metals are found in veins, or the combinations which they present, are extremely various. In a few cases they occur in the metallic state, nearly or quite pure, and these are termed *native;* but generally the qualities of the metal are disguised by some *mineralizer*, such as sulphur, arsenic, or oxygen, and these ores are again variously modified by the presence of other extraneous substances, leaving much to the industry and skill of the metallurgist, before the metal can be *reduced* or brought by various chemical processes to its pure form, to the state in which it is required for the purposes of the manufactures and of the arts.

CARCLAISE TIN MINE.

SECTION X.

Of the Decomposition and Decay of Rocks.—Agencies of Water, and of Changes of Temperature.—Relative Durability of Rocks.—Sources of Reproduction.

In the foregoing pages, occasional allusion has been made to the relative permanence of the rocks that encrust our globe, and to the agents which give rise to their disintegration and decay; subjects which I propose now to pursue more in detail, and especially to examine the cause and apparent ends of those mechanical and chemical processes going on in the great laboratory of nature, tending to a gradual change of the present appearance of the earth's surface, either by the wearing away of its strata, or by the accumulation of materials, which, by their slow consolidation, appear to be forming new ones.

In the animal, and in the vegetable creation, the elementary substances are in a perpetual circle of modification. The seed expands in the ground, the plant thrives, the tree is formed, it produces its flowers, fruit, and seed, it grows old, declines, and decays, being resolved into those substances, by the union of which its various forms and products were at one time or other composed. New plants arise from its decayed parts, and these attain their youth and age, and decay in various times, and under different circumstances, but still presenting us with the same unaltered succession. In the animal creation, one generation succeeds another with equally unerring uniformity; and though in regard to both kingdoms of nature, some great catastrophe, or natural event, seems to have swept away genera and species that once existed, they have apparently been supplied by others preserving the same general characters, though perhaps differing in particular circumstances of form, habit, and propensities. Upon these changes our attention is the more immoveably riveted, from their immediate and obvious connexion with our own state, existence, and destinies; and we are less awake to those more slow and imperceptible changes to which the inanimate creation also is subject, and to which scientific inquiry and geological history necessarily call our observation.

If we look upon the landscape that surrounds us, we every where discern the fingers of that "slow but sure destroyer, Time," busy in modifying the present aspect and appearance of things. The bold and rugged outline of the mountain-chain, full of broken peaks, abrupt precipices, extensive rifts and caverns; the deepening of the valley beneath, covered with a fertile soil brought down by the neighbouring streams, and bound together and enriched by organic remains; the rapid and turbid river expanding into the calm and undisturbed lake, whence it again issues, as it were, in renovated purity, and with new powers of fertilization,—are so many monuments of the devastation which a former order of things has suffered, and the records of the changes that are now going on. Let us examine a little into the powers whose aggregate influence is producing these effects, and endeavour to trace the purposes which are thus fulfilled in the general, as well as in the particular, economy of nature.

And first, among the great powers of matter active in producing these changes, heat and cold are obviously at all times concerned in exciting dilatations and contractions, and thus keeping up a perpetual but varying motion among the particles upon which they act. Of such changes, the sun is the grand source, to whose varying influence the earth, in its diurnal revolutions upon its axis, and in its annual circumvolutions through space, is always exposed. It may seem that the mere influence of change of temperature derived from the solar rays, must be of little efficacy in disintegrating hard and solid substances: but when we reflect upon the very considerable range of natural temperatures, and on the great receptive and emissive powers, in respect to radiant heat, which the surfaces of some rocks present, very considerable transitions from heat to cold, and the reverse may ensue, and acting upon certain textures, may alone lend powerful aid to the general work of decay.

When the influence of heat is conjoined with the varied agencies of water, the powers of destruction will not only be materially increased, but rendered, in many instances, rapid and irresistible. About two-thirds of our globe may be regarded as covered with the waters of the ocean, having, according to La Place, a mean depth of about four miles. Now, in the first place, this immense body of water, kept in continual motion and fluctuation by the attraction of the moon, and by the influence of winds, contributes materially to diminish the solid boundaries which are opposed to its inroads. How legibly are such effects recorded upon the bold and rocky coasts that environ many parts of our island. Their irregular and precipitous outline, the deep gulphs and projecting promontories by which they are indented; the evident relation of these and similar irregularities to the soft or hard structure, and destructibility of the rocks, as well as to the situation of the shore and force of the waves, show how much the present aspect and extent of the shore has been influenced by the action of the sea. The barren and abrupt cliffs which hang over the deep, the strata hollowed and carved out into all kinds of forms and irregularities, sometimes perforated into natural arches, insulated into columns, or divided into small and scattered islands, are similar and not less unequivocal proofs of the gigantic force and gradual inroads of the ocean, and exhibit so many various stages of destruction; and on such shores, the fragments of rock, once detached, become instruments of further destruction, and make (as Mr. Playfair has expressed it) a part of the powerful artillery with which the ocean assails the bulwark of the land. They are impelled against the rocks, from which they break off other fragments, and the whole are then ground against one another; whatever be their hardness, they are reduced to gravel, the smooth and round figure of which is the most certain proof of a detritus which nothing can resist.

Upon flat shores, it is true that an opposite effect appears often to be carrying on, and that there the land seems sometimes to be gaining upon the ocean. Still, however, we are to recollect that the materials thus depositing in the form of sand, or of various agglutinations of siliceous and calcareous matters, is derived from the neighbouring hills; and thus, that what the land gains in extent, it loses in elevation; and that as far as this source of its increase is concerned, it is actually a monument of its decay, announcing depredations elsewhere, and showing a mere removal of materials.

Let us now turn our attention to those joint agencies of heat and water, which are connected with its evaporation, and with the formation of rivers. Water raised in vapour is rendered portable even upon the wings of the lightest breeze, and is wafted with greater facility than air itself, into the high and mountainous regions of the land. Where these are of sufficient elevation, it is deposited in the form of frozen mists upon their summits, and gradually accumulating, forms those immense deposites of snow, which, by their own weight, slide down into the neighbouring vallies, and thence descend even into the plain, forming glaciers, and thawing into torrents, which, by their union, ultimately constitute the river that returns its waters to the ocean, whence they again circulate in the same round. Or if the country is comparatively low, if there are hills instead of mountains, and soft and yielding strata, in place of the hard and durable materials of the primary mountains, the precipitated water there filters through the various crevices, and, finding an exit in some of the neighbouring lowlands, quietly contributes to the springs and fountains which fertilize the adjacent vallies, and which ultimately uniting into brooks and rivulets, gradually augment their forces, and widen into some gently-flowing stream. Thus the magnitude, the power, and the extent of a river will depend upon the circumstances of its origin, and the nature of the country in which it takes its rise; but it in all cases exhibits to us the result of a perpetual distillation from the ocean, the waters of which are transported to the most inland situations, and tend, in their return to the sea, sometimes to harrow up and destroy, but always to fertilize and adorn part, at least, of the soil and country through which they return to the deep.

It is contended by the Huttonian geologists, and indeed in some places seems obvious, that the valleys in which rivers run are the work of their own waters. Sometimes it is true that we remark some vast chasm in which a river pursues a turbulent and irregular course, and which from its abrupt and angular lines, as well as from the nature of the adjacent country, and that of the intersected rocks, seems to announce some great and sudden convulsion, by which the channel it now occupies has been formed, and of which the sides or walls are rather rent and torn asunder, than worn by the slow operation of the waters. This is, for instance, the impression which we receive on examining the shattered and rugged crags over which the river Fyers falls, and which have been adverted to in a former section.

Such cases, however, are among the numerous exceptions to which all geological generalizations are liable; and rivers, when examined as to their course and effects, instead of appearing to flow in valleys formed for their reception by some accidental cause, seem often to have cut their own channels, slowly but surely excavating and eroding the land, and engraving that curious assemblage of lines upon the surface of the globe, which the trunks and branches of rivers exhibit. This is Huttonian doctrine; and if we now suppose this process going on through a long succession of ages, and when the earth's surface was in a very different state from that which it now presents, when perhaps the primitive chains of mountains were covered by other more yielding strata, it is obvious that the destructive effect of water would be much greater in some places than others; that certain strata would, from their softness, perhaps even from their solubility, yield rapidly to its action; and that others would long resist even its impetuous and utmost attacks, and that it might therefore be expected that a succession of lakes and cataracts did once exist in many rivers, which have been obliterated. To put this subject in a clearer point of view,—let us inquire how far the present beds and channels of rivers exhibit traces of such changes, and then compare this former order of things with the phenomena belonging to our present lakes and waterfalls; thus we shall be able, without the assistance of theory, to form an idea of the decay and detrition which rivers occasion, and of the various causes which have contributed to modify their effects, and establish or alter their courses.

In the first place, successive terraces upon the mountains and hills that form the sides of the valleys in which some rivers now flow, as well as the nature of sand and alluvial matter of the valley itself intersected by the present bed of the river, show that the verdant slopes and picturesque declivities, which constitute its present boundary, were once covered by its waters; that they were, in fact, the bottom of lakes, and that the chasm or opening, by which the waters now find their ready exit, did not exist at some former period, but has arisen from some gradual or sudden breach effected in a weak part of the boundaries of the great basin of water that once covered the country. Of the operation of such causes, in the production of the parallel roads of Lochaber, we have formerly spoken; and in further proof of the mode of their formation, we may notice the rounded masses and fragments of rock which lie upon the shelves, and which resemble those often seen upon the margin and in the shallow water of Alpine lakes: and also the difference of the soil in each valley above and below its highest line of shelf; all above this natural division being found to resemble the bare moorish soil which usually covers mountains, whilst large depositions of alluvial clay, sand, pebbles, and gravel, present themselves everywhere below that point, and are especially accumulated at the mouths of the different valleys. (*Ed. Phil. Trans.* IX., 12.) And again, wherever an isolated hill happens to arise from the bottom of the valley to a height above that of the level of any shelf, a line runs round it at a level corresponding to that of the shelf on the mountains of the side of the glen. These circumstances, then, render the evidence of the aqueous origin of these roads or shelves irresistible, and the absence of all marine exuviæ may be considered as showing the absence of the inroads of the ocean. Let us now suppose a deep hollow, between mountains rising with steep acclivities, to have been formed by great mountain-torrents coming perhaps from heights now no longer existing, or formed in any other way, and that such a hollow is partly filled with water, then the agitation of the surface of this water will tend to wear away its banks, but all being quiet beneath, it will not be elsewhere affected. The water will thus occasion the falling down of part of the materials from above, the finest and smallest of which will be washed away and sink to the bottom, while the larger masses will remain, and slowly accumulate upon the brink, forming a shelf, the width of which will vary with the nature of the surrounding rocks. Now we know that all the great lakes of mountainous countries are nearly of this description, and it is evident that the sudden escape of a part of the water of such a lake would produce an appearance resembling that of the parallel roads. Mr. Dick in the paper in the *Edinburgh Philosophical Transactions* already quoted, has instanced, in illustration of such a catastrophe, the valley of Subiaco, in the Apennines: following the course of the river Teverone upwards from the town of Subiaco, (which is an Italian corruption of *Sublaqueum*, by which name it was once known,) the mountains soon narrow into a very deep glen, which is suddenly blocked up by a rocky wall about one hundred feet high, and three hundred in thickness, and which is rent asunder, as it *seems*, at least, having a perpendicular chasm traversing it only twelve or fifteen feet wide, and occupied by the passage of the river. This barrier is perpendicular towards Subiaco, but upon the other side, which looks up the river, it presents a gradual slope. Having got beyond this rock, the river runs in a deep and precipitous valley, and high up on the face of the hills on the south side, are the remains of the baths of Nero, and the mouth of the aqueduct by which Appius Claudius conveyed water to Rome from the lake which originally filled the valley to that height; and on a level with these, extending round the whole of the neighbouring hills, is a parallel road. This lake and aqueduct are mentioned by Tacitus (*Ann.* lib. XI., cap. 13), and what is remarkable, the same historian, adverting to the residence of Nero, mentions the fact of the Emperor having been alarmed by prodigies whilst in that retreat. *When* the lake broke its boundary, either by washing out a vein of some soft material contained in the crevice, or *when* the strata were disturbed by any other cause, is not on record; but it probably took place after the sixth and before the tenth century. The original passage of the river over the boundary, is shown by the crust of travertino tufa, or stalactite, which encrusts the limestone rock, and which exactly resembles that now forming at Tivoli.

But it is not necessary to go back beyond our own times for events analogous to those which are recorded by the parallel roads, and by the vale of Subiaco. Only a few years ago a lake burst its barriers in the Valais, and the rush of water carried destruction before it as far as Martigny. Similar inundations are adverted to by Saussure, who says that in some part of the Alps where the rocks are composed of easily-disintegrating schist, dreadful accidents occur, from accumulations of water in its natural basins and cavities, which often burst the crumbling sides of their reservoirs, and descend with a terrible impetuosity in the state of a liquid mud, mixed with fragments of slate and other rocks. The impulsive force, he says, of this half-liquid, half-solid mass is beyond description. It tears down rocks, eradicates trees, destroys buildings, and overwhelms and desolates the fields, by excavating deep ravines, and covering the surface with fragmented rocks, gravel, and mud. To compare great things with small, those who remember the bursting of a vat a few years ago in Meux's brewery, may form some notion of the catastrophe derived even from a very small natural accumulation of water breaking suddenly upon the neighbouring territories.

Thus, then, we have considered some of the most important evidence of the destructive powers of water, as rendered apparent by the nature of the beds of rivers, by the excavation of valleys, by the worn and broken aspect of rocky coasts opposed to the unceasing warfare of the ocean's waves. If we combine these abstract powers, as it were, of water, with those which it derives from changes of temperature, its energies as a destructive agent become more rapid and irresistible. Many substances of a spongy texture absorb it in considerable quantities, and the contractions and expansions which it suffers in their pores tend to their rapid disintegration. This we see in chalk and sandstone, in Bath and Portland stone, and in several other materials, which are thus crumbled down and worn into dust, often with a surprising degree of celerity. Several of the public buildings of London furnish illustrations of this truth; many of the modern structures in Oxford are already more decayed than their ancient neighbours, constructed of less porous stone. In Henry VII.'s Chapel, as it appeared before its recent renovation, all the laboured sculpture and Gothic fretwork was worn and eaten away in the course of three hundred years, and now it has been modernized at great expense, in the very same material. Indeed, in respect to all these substances in nature, we remark in their rounded outline, in the debris that covers their surface, in their eroded and undermined walls where exposed to the action of the waves, and in the turbid waters of the springs and streams that descend from their summits and sides, the extreme facility with which water, aided by changes of temperature, effects their wearing away and destruction. Its powers in this respect are also truly gigantic upon certain rocks, which, from a laminated or flaky structure, admit it into their crevices, where it freezes and thaws alternately, and thus gradually loosens enormous flakes and masses, which, sliding down their precipitous sides, shatter and fragment the surface, accumulating below in such quantities as to form a hill at the foot of the parent-mountain. Such appearances we see on some parts of the coast of Cornwall and Devon, in many parts of the great schistose ridge in North Wales, and more decidedly in the softer shales, as of Derbyshire for instance, where, in the elevation called Mam Torre, masses and fragments are perpetually descending, and have accumulated into a daily-increasing hill.

But with these mechanical agencies of water its chemical powers are frequently combined, and its *solvent* agencies (in a pure state often very considerable) are augmented, as far as *certain* rocks at least are concerned, by the absorption of carbonic acid, derived frequently from the atmosphere, and frequently from subterranean sources. Thus it is that the waters which traverse limestone districts are often so loaded with calcareous carbonate, as to deposit it upon their banks and precipices in the form of *tufa*, or to petrify substances accidentally thrown into the stream or fountain, as we see in the petrifying well of Matlock; or where these waters trickle through the ceilings, and pervade the walls of those natural caverns in which limestone strata abound, they stud their sides with an infinity of brilliant crystalline deposites, or form depending stalactites, that hang from the roof in a thousand fantastic forms; or in other cases, they slowly deposit their once-dissolved contents, so as completely to obliterate entire cavities, which thus become quarries of that beautiful lamellar spar called *stalagmite*. Of all these peculiarities in the action of water upon limestone strata, Derbyshire furnishes instructive and interesting illustrations; and in the caverns in the calcareous sandstone of Fontainbleau, the yet more remarkable phenomena of the crystallization of the carbonate of lime enveloping sand, so as to alter its texture, but not its form, occurs. Lastly, let us ascend to the primitive rocks, and among them we shall find that even granite itself is open to the attacks and inroads of one or other, and sometimes of all, the decomposing and destructive agents which we have enumerated. Some of its varieties are, it is true, extremely permanent, even in mountain masses, and seem almost imperishable, when considered in respect to their uses in the arts. Witness the mighty remains of the ancient Egyptian sculptors, executed in this hard and durable material; or look at the high state of preservation which some ancient temples, of a very remote date, present, and which still stand nearly perfect, amidst the fragments and dust of contemporary edifices, constructed of marble and other softer kinds of stone, as proofs and illustrations of these remarks. The beauty of granite, as a modern building material, may be seen in many of the public edifices of Dublin; and when we reflect upon the ease with which it may be brought into this metropolis from various parts of the British dominions, by water-carriage, one is involuntarily led to regret the continued use of Portland and Bath stone in some of the magnificent works now in progress. To these remarks however, Waterloo Bridge and the New London Bridge furnish splendid exceptions, and the material of which they are constructed, no less than the grand simplicity of the designs, and the perfection of execution, unite to constitute them fitand durable public memorials of the genius and skill of the architect.

The decay of granite, considered in relation to its mountain masses, is effected in various ways, depending upon the structure and composition of the rock. In Cornwall, for instance, there are large patches of granite so soft and yielding, that it may be rubbed to powder between the fingers, and the grains of quartz and mica may be separated from the pulverulent felspar, which is the ingredient that undergoes decomposition, and forms a fine white powder, which is washed out of the rock by the rain and streams that percolate the district. A very striking assemblage of these decomposing granite hills is presented in an excavation near St. Austle, in Cornwall, known by the name of Carglaise Tin-mine. The veins of ore are harder than the rock itself, and easily traced upon its rapidly-decaying surface; and every rill of water that traverses the works is loaded with that finely-divided felspar, so abundantly deposited in all the lowlands of the neighbourhood, and largely exported, under the name of Cornish or Porcelain Clay.

At the Land's End the granite is of a very different character, and does not suffer that chemical change, which probably consists in the abstraction of the alkaline matter of its felspar, causing it to disintegrate in the manner just described; but there it splits into natural blocks, which are gradually removed from each other by the congelation of the water that gets between them; and where the surface is precipitous, they are thus often dislodged, and fall into the valley, or upon the beach beneath. The tendency of these square blocks to yield at their edges and angles to the weather, and thus to acquire a spheroidical appearance, independent of attrition by water, has already been adverted to in mentioning the granite Tors of Cornwall.

In other granitic districts, the structure of the rock is more decidedly lamellar, or stratified, and the direction of the fissures vertical, or nearly so. Sometimes they appear made up of successive layers, a texture seen in many of the Alpine peaks of Mont Blanc; and where this is the case, their decay produces that jagged and irregular appearance which we see, for instance, around the summit of Mont Anvert, forming the *needles* of Chamouni. When to these causes of destruction we unite the effects of those enormous accumulations of ice and snow, constituting the Glaciers of the Alpine regions; when we see these immense mountains, for such they are, composed of aggregated masses of rocks and ice, continually travelling into the valley, and, acted upon by the elevated temperature, thawing into rivers, or suddenly falling from their elevated stations, and destroying every thing in their path, it is impossible not to be forcibly impressed with the great work of destruction which is thus carrying on. Indeed, we can scarcely pass an hour amongst the mountains that border Mont Blanc, without seeing or hearing an avalanche, falling with a noise that equals the most tremendous thunder-clap, from some of the neighbouring heights.

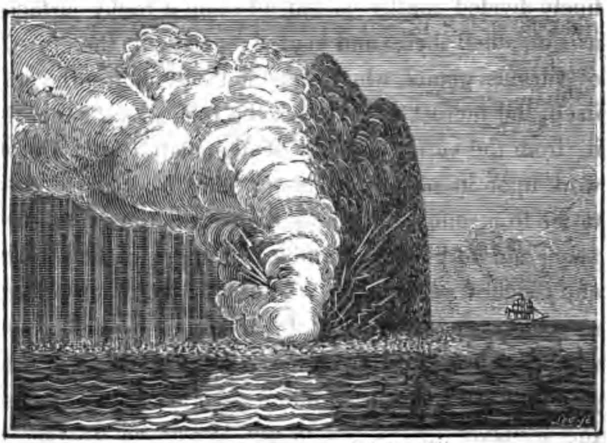
We have now considered the principal agents by which the disintegration and decay of rocks is effected; and have witnessed, as the joint result of their operation, a continual wearing away of the strata, to such an extent, indeed, that, in the progress of years, some geologists have anticipated the entire disappearance of all irregularities upon the earth's surface. Thus the Huttonians would have us believe, that the countries that are now so beautifully diversified with hill and dale, and the mountains that shade and fructify the valley by their streams, are to be worn down into arid deserts—their materials are to be transported into the ocean—and the globe again become covered with the waters of the deep. And if we go back in our imagination to a former period of the earth, we may suppose that, since the same operations have been going on for ages, those great chains of mountains, whose present state we have just contemplated, are themselves but the remains of masses infinitely greater and more lofty; that perhaps they have been covered with other materials, and that these have been abundantly removed. Of such removal, it is presumed, we often have distinct evidence in the insulated masses of trap-rocks, which, if thrown up in a fused state into their present situation, must necessarily have been surrounded and supported by materials, the subsequent removal of which now exhibits the naked and insulated mass.

Such are at least some of Dr. Hutton's *principia*—his theory regards all the materials of our present strata as on their road to the deep—it allows of no exception to the law of decay. But as the Author of Nature has not given laws to the universe, which, like human institutions, carry with them the elements of their own destruction; as he has not permitted in his works any symptom of infancy or of old age; it was necessary in this theory to provide for reproduction, and such a provision Dr. Hutton has derived from the agency of submarine fire, by which the substances now accumulating in the depths of the sea are to be again agglutinated and elevated. "From the land now going to decay," says Mr. Playfair; "from the sand and gravel forming on the sea-shore, or in the beds of rivers; from the shells and corals which, in such enormous quantities, are every day accumulated in the bosom of the sea; from the drift-wood and the multitude of vegetable and animal remains continually deposited in the ocean—from all these we cannot doubt that strata are now forming in those regions to which nature seems to have confined the powers of mineral reproduction, and from which, after being consolidated, they are again destined to emerge, and to exhibit a series of changes similar to the past."

If, however, we examine the progress of this decay a little more closely, we shall, I think, discern several intermediate opposing agents, which the Huttonian theory overlooks, and shall perhaps be inclined to consider the changes that are going on, rather as tending to increase the habitable surface of the globe, to add to its beauty, to its fitness for the support of life, to convert uninhabitable and barren portions into fruitful and populous territories. Such, at least, has been their effect—such seems to be their present operation—and such their ultimate end. Let us, therefore, briefly inquire into the compensating and regenerating effects of the causes we have enumerated, independent of that ultimate reproduction at which the Huttonian theory points.

In the first place, the formation of soils, by the washing down of finely divided earthy particles from the mountainous land, and their accumulation in the plain or valley, or upon the shelves or horizontal ridges of the hills, naturally attracts our attention as an important and beneficial consequence of this universal degradation of the globe. Of this finely-divided matter, it is true that a very great portion forms the mere mud of rivers, but where they are slackened in their progress, or where they widen out into lakes, they slowly deposit it upon their banks, increasing the extent of the neighbouring meadows, and diminishing their own boundaries. We see the troubled waters of the mountain stream again issuing from the lake, pure and pellucid —we observe the lake slowly filling up, and its sandy accumulations, bound together by the reeds and grass upon its banks, resist the fluctuations of its waters, and soon become firm ground. Of this the lakes of Scotland and of Cumberland furnish abundant proofs, but the lake of Geneva presents us with the most grand and instructive illustration. That immense basin of fresh water is, like all other lakes, gradually diminishing in mean depth; the Rhone, with its countless tributary streams, is seen pouring its abundant waters, turbid with the débris of the great Alpine chain of the Valais, into the eastern end of the lake; there the river is always loaded with finely-divided matter, and muddy and opaque, but when it again issues from the opposite extremity, its waters are of the brightest hue; and as it hurries its divided streams through the streets of Geneva, the observer's attention is always arrested by the peculiar blue tint which announces its extreme purity. This is the history of all lakes, and these again are but the types of the ocean itself—that great reservoir, into whose depths all the impurities of the land-streams are ultimately consigned, and from which the waters are again raised in renovated purity, to return to the earth in fertilizing showers, or to be condensed into streams, and accumulated into rivers and lakes by the summits of hills and mountains. What may be the effect of various and contending streams in the bosom of the deep, or what the exact arrangement and final distribution of the matter carried into it—to what new agencies it may there be liable, or to what modifications of the known powers of matter, can scarcely be surmised; but we know thus much for certain, that no inconsiderable portion of it is thrown up in the form of bars and sandbanks, at the mouths of rivers—that shallows are formed upon coasts—that it is frequently agglutinated upon flat and shelving shores into new strata—and that much is modified by the incessant labours of zoophytic animals into coral and madrepores, of which enormous shoals, and islands, and even parts of continents, are visibly formed, and of which there no doubt exist enormous and unknown accumulations in hitherto-unexplored regions. In short, the aggregate effects of the labours of these microscopic animals surpass all calculation. They probably commence their work upon some submarine rock, and it is continued by successive races till the enormous wall of coral reaches the surface. The care to raise it perpendicularly shows, says Captain Flinders, a remarkable instinct in these diminutive creatures; and being generally built where the winds are constant, it affords a shelter, upon the leeward of which their infant colonies may safely be sent forth. To this instinctive foresight it seems to be owing that the windward side of a coral-reef, exposed to the open sea, is generally the highest part, often rising from the depth of some hundred fathoms. These animals always work under water, but the sand and broken remnants thrown up by the sea adhere to the reef, and form a solid mass as high as the tides reach. The new bank is then visited by gulls and other sea-birds; marine vegetables next take root upon it, and a soil begins to be formed. Perhaps a cocoa-nut is thrown up by the water, or land-birds visit it, and deposit the seeds of shrubs and trees. It thus gradually assumes the form of a verdant island, and, lastly, man becomes its possessor.

Thus we see that if, on the one hand, destructive agents are continually at work, renovation is also going on; sometimes by mechanical operations, and at others by the labours of various animal tribes, regeneration of surface is effected to a remarkable and unexpected extent. To this end the vegetable creation is also conducive, and when, by some of the operations which we have considered, a stratum of finely-divided matter is lodged upon a rocky surface, it is detained there, and matted together by the growth of various plants, which thus not only detain the soil itself, but incrust and protect the rock which supports it, from the various agents of degradation that are at work upon its naked neighbour: heath attaches vegetation to a sandy soil; moss fixes it upon a rocky surface, and herbs and brambles interweave their roots and render it permanent. Under these circumstances, as soon as decomposition of a rock commences, asperities are softened down, and steep and abrupt precipices gradually converted into regular and gentle slopes; the seeds of lichens, which are constantly floating in the air, make these their resting-places; their generations occupy it till a finely-divided earth is formed, capable of supporting moss and heath. Acted upon by light and heat, these plants drink in the dew, and convert the constituent parts of the atmosphere into nourishment. Their death and decay afford food for a more perfect species of vegetable, and at length a mould is formed, in which even the trees of the forest fix their roots, and which is capable of rewarding the labours of the cultivator.



VOLCANO IN THE ISLET OF SABRINA.

SECTION XI.

Phenomena of Hot Springs, Earthquakes, and Volcanoes.—Submarine Explosions.—Extinct Volcanoes.—Vesuvius.—Etna.—Theories.—Conclusion.

In the preceding pages, we have examined the materials which compose the strata or crust enveloping our planet; we have inquired into the order of their succession, into the nature of their component parts, into the evidences which they exhibit of the destruction of a former order of things, and into a few of the theories which have attempted to account for their origin and successive changes. We were thence led to consider the alterations which they are suffering by the slow action of the elements, and the causes and effects of their wearing down and decay. Thus have we found that although the inanimate creation is in a state of apparent quiescence and repose, gradual operations and unheeded processes are everywhere carrying on, which, though not apparent to the superficial observer, display to the more inquisitive eye of science a series of wonderful and often unexpected causes, tending to the production of the most beneficial effects, and opening new evidence of the design and harmony that pervades the world. And if we, imperfect in our comprehension, and limited in our powers, dwelling upon an insignificant point in space, and scarcely attaining the use and perfection of our senses before we are summoned from the scene, are even now permitted to discern thus much in the economy of the creation, what, may we not naturally ask, must be the extent of causes and effects hitherto unknown and undiscovered; but preserved, as it were, to awaken the industry, and reward the toils of future inquirers, and partly destined, perhaps, to be unfolded when the human race shall have risen in the system of being, to some unknown point of moral and intellectual perfection?

But, incessant as these changes that surround us are, they exhibit nature and her operations in a state of seeming inertness and repose, compared with the sudden and terrible devastation of the earthquake and volcano—to the consideration of which the progress of our subject now brings us.

In entering upon this extensive and interesting inquiry, all particular descriptions and details must necessarily be avoided, as incompatible with our present object; so that I shall endeavour, from the history of earthquakes and volcanoes, to select, in the first place, a succinct account of their concomitant phenomena; we shall then attend to the changes which they effect in the country or strata which they invade; and thence, by a reference to the known physical and chemical habitudes and powers of bodies, we may endeavour to trace the agents concerned in their production, and thus arrive at their final cause.

That the most active chemical powers of matter are called into action in certain strata of the earth, is demonstrated by the frequent occurrence of hot springs of water thrown up from below, of a temperature greatly above the mean heat of the earth, and not uncommonly approaching, or even attaining, its boiling point. Hot springs are not uncommon in most parts of the world where volcanoes are unknown; but in their neighbourhood, and in volcanic districts, generally, they are common and abundant; and sometimes, as in the Geysers of Iceland, jets of boiling water are thrown up, with explosions and concussions of the earth. But although we have these gradations in the temperature of springs, and though in one case the phenomena approximate to, and in another recede from those of volcanoes, we are probably to look to one and the same cause for the production of these modified effects. Now, there are numerous substances, of which even the slow and gradual chemical action is attended by increase of temperature, and which, under certain circumstances, may become the source of most intense heat; and these, in the contact of water percolating the strata, would amply account for its elevated temperature: here, however, the *purity* of the water renders such an explanation inadmissible; and it has been supposed that water, thus originally heated, sends forth its vapours through the crevices of the rocks, and that the steam thus generated is condensed by and communicates heat to some pure and distant subterranean stream. Such at least is the only plausible theory of thermal springs; and the alternating jets, explosions, and concussions, that sometimes attend them, and that more especially characterize the boiling fountains of Iceland, have been referred to the escape of steam under compression, and to the mechanical impulse of its condensation, upon the water, which is well known to produce a peculiar cracking noise and explosion even upon a small scale. The waters of the Geysers, however, are far from pure; and, unlike those of Bath, Bristol, Buxton, and Matlock, in this country, they contain a large quantity of siliceous earth in solution, which they deposit in the form of an incrustation or tufa, upon the surrounding basin; and some of the springs are contaminated by other substances, which are mechanically suspended in them, rather than chemically dissolved.

In the phenomena that attend earthquakes we have yet more decided evidence of the existence of subterranean fire and heat; and it will not be difficult to trace out their connexion with volcanoes, and their probable dependance upon one and the same cause.

Upon the atmospheric phenomena that are said to precede earthquakes, much dependance cannot be placed; and a low barometer, a very dry season, an electrical atmosphere, thunder-storms, and auroræ boreales, may, or may not, precede and attend an earthquake—they are, at all events, very uncertain precursors. The serenity of the air immediately antecedent to the shock, the agitation of the ocean, and the disturbance of springs and fountains, are also very equivocal symptoms. In short, the only unvarying attendants upon the convulsion are those immediately dependant upon the chemically-acting substances, explosions and noises, attended by concussion more or less violent, by rifts and ruptures of the strata, by the occasional emission of hot air or even of flame, and by sulphureous and other fumes dependent upon the combustion of various bodies, to which the cause of the other symptoms is to be referred.

The noise that attends an earthquake is very differently described; sometimes it is like the rumbling of distant thunder, or the blowing of a violent wind;

a rattling like that of carriages over an uneven pavement is also commonly heard, and even explosions like those of large pieces of artillery; then the ground trembles, or its surface is heaved to and fro, sometimes in a perpendicular and sometimes in an horizontal direction, and great rifts and fissures are formed, from which water, mud, smoke, or fire issue, and which enlarge into chasms that swallow up the former surface; large lakes are sometimes suddenly dried up; rivers alter their courses or are lost; the sea itself is also greatly disturbed, and subject to changes no less remarkable than those occurring on land; shallows are often formed in deep water; mountains are even raised from the bottom of the deep, and currents of air, smoke, and various gases, and even of flame, are seen to issue from the water.

Among the numerous records of earthquakes, I shall select that which destroyed Lisbon in 1755, as containing an epitome of all the disastrous effects and concomitant phenomena of these most awful and destructive visitations.

In the first place, it deserves notice that the approach of the great shock was gradual, and that, for three or four years antecedent to it, several considerable tremors of the earth had been perceived. On the 1st of November, at half-past nine in the morning, a rattling noise, like that of distant thunder, immediately preceded several short and quick vibrations, which shook the very foundations of the city, so that many houses instantly fell; there was then a short pause, and a swinging motion followed, which laid the greater part of the houses in ruins, and destroyed thousands of the inhabitants in less than six minutes. The bed of the Tagus was in many places elevated; ships were driven from their moorings; and the pier, upon which were several hundred persons, sunk to an unfathomable depth. The bar of the river was at one time quite dry, but suddenly the sea rolled in, and covered it with sixty feet of water. At Colares, twenty miles from Lisbon, the earth was also agitated and rent asunder, emitting smoke and flame. St. Ubes, twenty miles south of Lisbon, was swallowed up, and the sea every where inundated the coast, and threatened the destruction of Cadiz. At Gibraltar there were the same extraordinary ebbings and flowings of the tide; and there the most violent shock was felt about an hour later than at Lisbon, and at about the same time as at Madrid, where persons walking the streets were turned sick and giddy, but where little other mischief ensued. This same earthquake destroyed Algiers; and a great part of the city of Morocco, near which from eight to ten thousand people were engulphed, and the earth again closing, were seen no more. Various towns upon the African coast of the Mediterranean also suffered. At Madeira, the shock was felt nearly at the same time as at Lisbon. The sea rose fifteen feet above high-water mark, and did great damage. Over the whole of Europe the effects of this earthquake were more or less perceived, and when the violence and extent of the mischief at the immediate scene of its action is considered, one is rather surprised that the damage should not have extended beyond the limits that have been mentioned.

We may refer to the various printed accounts of this and other earthquakes for further details as to particulars, the evidence before us being amply sufficient to prove that the phenomena are referable to some sudden and powerful chemical actions going on at great depths below the earth's surface; while the flame, smoke, and other appearances common to volcanoes, show the connexion of the two effects, and lead us to refer them to one cause—the explosions and agitations of the earthquake being analogous to those which might be expected to occur from volcanic eruptions wanting vent, and exerting their force upon the solid vaulting of the superincumbent strata.

But the immediate connexion between earthquakes and volcanoes may often be very satisfactorily traced. Pallas says, that on the 5th September, 1790, a subterraneous rumbling seemed to issue from the Sea of Azof, and then, with an explosion like that of a piece of ordnance, an island emerged from water thirty feet deep; it was of a conical form, and ejected mud, stones, smoke, and flame, and the surrounding country was severely shaken at intervals during the day by repeated shocks of an earthquake.

In January and June, 1783, Iceland was severely agitated by earthquakes, and a dreadful volcanic eruption burst forth in the sea, at its south-west extremity.

In June, 1811, Captain Tillard, on approaching the island of St. Michael, observed, rising in the horizon, two or three columns of smoke, which proved to issue from a marine volcano, about a mile off the north-west end of the island, whither he proceeded, more nearly to inspect the phenomena. "Imagine," he says, "an immense body of smoke rising from the sea, the surface of which was marked by the silver rippling of the waves, occasioned by the slight and steady breezes incidental to those climates in summer. In a quiescent state, it had the appearance of a circular cloud, revolving on the water like a horizontal wheel, in various and irregular involutions, expanding itself gradually on the lee side, when suddenly a column of the blackest cinders, ashes, and stones would shoot up in the form of a spire, rapidly succeeded by others, each acquiring greater velocity, and breaking into various branches resembling a group of pines, these again forming themselves into festoons of white feathery smoke. During these bursts the most vivid flashes of lightning continually issued from the densest part of the volcano, and the columns of smoke rolled off in large masses of fleecy clouds, gradually expanding themselves before the wind, in a direction nearly horizontal, and drawing up a quantity of water-spouts, which formed a striking addition to the scene. In less than an hour a peak was visible, and in three hours from the time of our arrival, the volcano then being four hours old, a crater was formed, twenty feet high, and from four to five hundred feet diameter."

The account then goes on to state, that the eruptions were attended with a noise like the firing of cannon and of musketry intermixed, as also with shocks of earthquakes, sufficient to throw down a large part of the cliff on which the observers stood. Captain Tillard afterwards visited the volcanic island: it was eighty yards high; its crater, upon the level of the sea, was full of boiling water; it was about a mile in circumference, composed of porous cinders and masses of stone.

This incomplete abstract of Captain Tillard's paper* is sufficient for my present purpose, that of connecting the phenomena of boiling springs and of earthquakes with those of volcanoes; and taken in connexion with the similar histories to which I have adverted, and with others that are upon record, but which I have not thought it necessary to quote, seem to show that, if we can discover the efficient cause of volcanoes, that of earthquakes and their concomitants may be referred to the same source. I shall therefore now briefly advert to the history of volcanoes, and thence endeavour to trace, upon analogical and experimental data, the probable causes of their various effects, and the sources of their tremendous powers of destruction.

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* Philosophical Transactions, 1812.

Volcanoes are not confined to any district or part of our globe, either geographical or geological. The Italian territory, and the southern extremity of the Mediterranean, present the most awful monuments of their devastation. In America the whole chain of the Andes is subject to the most terrible earthquakes, and from Cotopaxi to the South Sea, there are, according to Humboldt, more than forty craters in constant activity. Extinct volcanoes are by no means uncommon, and in the Vicentine territory there are rocks graduating from distinct lava into those varieties of basalt usually called amygdaloid. On the contrary, new volcanoes are exceedingly rare, and there are not more than two or three instances of these eruptions having broken out in new places; but then we are to remember that, as more than two-thirds of the globe are covered by water, explosions may take place in the depths of the ocean, and may not produce any observable effect, though they are sometimes announced by extraordinary perturbations of the waves, high swells, and even sometimes a volcanic mountain is thrust from the bottom of the sea, as happened, in the instance that I have already narrated, off the Azores, in 1811, in water sixty fathoms deep; indeed the soil and aspect of all those fertile islands, as well as of many of the West Indian isles, seems to indicate that they are of similar origin, and frequently are found to consist entirely of coral beds and volcanic formations.

The truly volcanic countries are remarkable for the conical form of their hills; the Bay of Naples furnishes a fine panoramic view of their general aspect, and one of the most prominent of the hills which surround it was raised, in the year 1538, in a single night, to the height of one thousand feet, and three miles in circumference. It may serve as an instance of the force and power of the volcanic elements.

In these countries the singular transmutations of surface connected with the history of their formation often deserve notice. Near Naples, for instance, the Lake of Agnano is evidently the crater of an ancient volcano. The cone of the Solfaterra is seen near it, and the Grotta del Cane upon its edge. There is, indeed, no country better adapted to illustrate the power of volcanic fires than the south of Italy, nor have the phenomena connected with them been anywhere more completely observed or investigated. Of the antiquity of Vesuvius, and of the prodigious quantity of matter which it has erupted, a good idea may be formed from the inspection of the subterranean ruins of Pompeii and Herculaneum, both of which were buried by an eruption of the mountain, in the first century of the Christian era. The former city is now twelve feet, and the latter about one hundred feet below the present surface; but these cities are themselves founded upon beds of lava. Thus we see that these tremendous agents have at one time destroyed countries of ancient formation, and at another created new territories, whose subsequent fertility has, as it were, counterbalanced the desolation that accompanied their productions. It need hardly be mentioned that the most delightful and celebrated portions of Italy have been either formed or modified by the agency of fire. The rock of the Capitol, which Roman vanity called *eternal*, is the tottering edge of a crater. The *Campagna Felice* is the obvious production of successive lavas, and owes its exuberant fertility to repeated showers of volcanic ashes.

Etna and its vicinity also present a magnificent and characteristic specimen of a volcanic country; and though so frequently destroyed by rivers of red-hot lava, and overwhelmed by torrents of fetid mud, and showers of sulphureous dust, its neighbourhood is covered with the most prolific vegetation and majestic forests. The height of this mountain is about ten thousand feet, and the ascent from Catania carries the traveller through various zones of temperature, until he reaches the black forest of firs and pines, above which the rugged, barren, snowy precipices announce his approach to the summit. The crater of this mountain is upon the most magnificent scale. It is about two miles in circumference, and bounded by black and tottering walls, in many places perpendicular, and upwards of fifteen hundred feet in height*.

The phenomena of volcanic eruptions of any magnitude have often been but imperfectly described, because the authors who have witnessed them have not been guided in their observations by scientific views: they have generally been overpowered by the tremendous and extraordinary phenomena that they have witnessed, and have rather endeavoured to transfuse into the minds of their readers the horrors and devastation of the scene, than to describe it with that minuteness which their opportunities would sometimes have afforded. Breislac is one of the most intelligent writers upon this subject, and both he and Sir William Hamilton have described the dreadful eruption of Vesuvius which destroyed Torre del Greco, in 1794. As these accounts are well known, I shall merely advert to such parts as tend to illustrate the nature of the substances ejected, and to throw light upon the ultimate point of our inquiry, namely, the cause of volcanic fires.

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* For a further description of Etna, see vol. xix. of the Quarterly Journal of Science, First Series.

On the evening of the 15th of June, 1794, after the neighbourhood had experienced several preliminary earthquakes, the base of the crater opened on the west, and ejected a torrent of lava, which in six hours flowed three miles, and after destroying the town of Torre del Greco, ran into the sea, forming, according to Sir W. Hamilton, a promontory upwards of twelve hundred feet in breadth, and six hundred in length; the lava contained augite and crystals of mica. On the 16th, the lava made its escape on the east side of the crater, and the mouth of the volcano continued to eject ashes for four days, which covered the adjacent country, and so obscured the atmosphere, that at Caserta, which is more than ten miles from Vesuvius, they were obliged to use torches at midday, and the gloom was only broken by frequent and vivid flashes of lightning, which played about the summit of the mountain. On the 20th, the ashes ceased to fall, and showers of red-hot stones were ejected, accompanied by a constant succession of dense vapours; and rain mixing with the loose ashes, formed impetuous and destructive torrents of mud; while carbonic acid and nitrogen gases, with small portions of sulphurous acid, contaminated the surrounding atmosphere, and diffusing themselves over particular districts of the country, were equally fatal to animal and vegetable life.

I might quote other cases and other accounts of volcanic eruptions, but it would be found that, with few exceptions, they agree in their main and principal points,—in their preliminary phenomena, in the nature and ejection of the lava, in the explosions of hydrogen gas and aqueous vapour, and in the production of mephitic gas; and such being uniformly the results, we may safely refer to them for a clue to the phenomena.

One of the earliest hypotheses to account for volcanic eruptions is, that which attributes them to the eructations of a perpetual central fire, to which, however, the nature of the lava, the method of its projection, and, above all, the known laws of the communication of heat, are insurmountably opposed. The sudden evolution of steam has also frequently been resorted to; indeed the power of this agent did not escape the genius of the ancients, for Lucretius, in his description of Etna, clearly ascribes the phenomena to its effects. They have also been referred to the ignition of beds of coal, and Werner supposed that the fire thus produced fused the circumjacent rocks, and formed lava. Others have called sulphur, pyrites, petroleum, and bitumen to their aid, but have sought in vain for the necessary supply of oxygen, without which these combustibles could not perform their required part; and, indeed, if we grant an unlimited supply of that element, the projectile force, the vapour, still remains to be accounted for. Others have imagined a great depôt of electric matter, pent up in certain submarine and subterranean caverns, and occasionally sallying forth to fuse and blow up the surrounding materials.

It appears to me that, among the most plausible theories of volcanoes, is that suggested by Sir H. Davy, soon after he had discovered the nature of the earthy and alkaline bodies. Indeed, it enables us, in most cases, upon just principles of sound analogy, to explain their origin; for lava consists of earthy and alkaline bodies ejected in intense ignition, and it is associated with vapour, with explosions of hydrogen gas, with the production of nitrogen, and, in short, there is every concomitant circumstance to lead to the conclusion, that there exist, in the bowels of the earth, masses of those highly inflammable metallic bodies constituting the bases of the earths and alkalies, and these and water are essential requisites for the production of the phenomena that precede, accompany, and follow the eruption of volcanoes; they may be referred to as accounting for the earthquakes, the explosions, and the gaseous products; and they are the *only* agents with which we are acquainted, capable of fulfilling all the requisites. How or where these bodies exist, at what depths, in what quantity, and how accessible to water, are questions that we cannot solve, and which, therefore, I shall not discuss, more especially as they are not necessarily connected with the main question before us, which merely requires their existence, and the presence of water; and it is curious that water is always found connected with volcanoes. Vesuvius, Etna, and Hecla are upon the verge of the sea; and in the vicinity of the burning mountains of the Cordilleras there are lakes; and it has been observed that springs and lakes suddenly dry up previous to the active eruption of a volcano*.

I have before adverted to the analogy that subsists between basalt and lava, and have endeavoured to show, that the appearances of the rocks and strata that are invaded by basaltic veins accord, in some respects, with the igneous theory of their origin. I have also noticed some singular facts connected with granitic and porphyritic veins, and have traced analogies which may serve as theoretical links to connect them with the basaltic formations. How far, then, are we able to trace a resemblance between these products and their effects, with those of ordinary and now extinct volcanoes? Although it must be allowed that, among modern lavas, we have nothing strictly like that crystalline aggregate of quartz, felspar, and mica, which we call granite, we have among them substances so closely resembling certain basaltic rocks, that it is difficult either chemically or mineralogically to distinguish between them; and in lava, crystals of mica are sometimes found, not accidentally blended with, but actually formed in it, and of substances differing rather in form than in composition from feldspar. Is it possible, therefore, that certain appearances exhibited by the strata of our globe, not referable to aqueous detritus, and evidently, indeed, unconnected with any probable agency of water, may have arisen from the more superficial existence of those inflammable metallic bodies; that their combustion and fusion may have left behind them those equivocal rocks; and that the limited duration and non-recurrence of such phenomena may be ascribed to the destruction of the agents which have produced them, and to the non-existence of those substances near the surface, which the phenomena of volcanoes induce us to believe are still, though probably sparingly, disseminated in particular situations?

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* A very different hypothesis upon the subject of volcanoes has been published, since the above was written, by Mr. Scrope, to which the reader is referred.

It is, however, unnecessary that I should here recapitulate the Plutonian and Neptunian evidence. The former, as modified by Dr. Hutton and his commentators, is that which most plausibly accounts for the phenomena, is least at variance with facts, is least hypothetical, and best entitled to the appellation of a theory of the earth; at the same time, I do not wish to be deemed assentient to every clause even of this portion of the Huttonian doctrines. Theorists always fly to extremes; and he that would profit by their opinions, must submit them to the balance, reject those that are light, and often recoin the others. "God forbid (says a celebrated writer) that man, whose teacher is the whole circle of nature, should be regarded as a mere lump of wax, upon which any Professor may stamp at pleasure his own conceited image."

It appears then that the terrestrial changes going on around us, both rapid and gradual, are subservient to the most beneficial effects, and that by operations apparently destructive, nature renovates her powers: from the decay of animated beings we deduce similar conclusions, and in inanimate nature, we now read the same great and exalted truths; we learn that the Author of nature has not given laws to the universe, which, like the institutions of men, carry in themselves the elements of their own destruction, but that His works are preserved in unchangeable perfection, and as it were in eternal youth. If there be any part of natural knowledge calculated to awaken in us the most profound sense of the excellence and perfection of Nature's works, it is surely in the subjects that have now been before us. That person is little to be envied who, beholding the immensity of the universe, and marking the majestic simplicity by which its operations are conducted, does not feel awakened to a higher species of being, and admitted into nearer intercourse with the Author of nature. In short, it is impossible to pursue knowledge without mingling with it the best sentiments of devotion, or to perceive the laws of Nature without at the same time discerning the hand of the Lawgiver. Thus, in every age and country, " the evidences of religion have advanced with the progress of true philosophy; and science, while she raises a monument to herself, at the same time erects an altar to the DEITY."

THE END.

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